New Scientist

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AI SOLVES IMPOSSIBLE MATHS PROBLEMS

WEEKLY 2 November 2024

SPECIAL ISSUE

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What is the one thing you should eat more of?

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Instant Expert

Get up to speed with the weird world of quantum mechanics, where nothing is as it seems until you measure it, in this one-day workshop. Six leading quantum physics experts will explain this famously complex field in easy-to-understand language. The event is perfect for those curious about the quantum world but who may not have a science background. On 9 November at London's Congress Centre.

newscientist.com/events

Online event

Journey to the poles

The Arctic and Antarctic are harsh yet beautiful regions that have fascinated scientists for centuries. In this free online event on 6 November, glaciologist Ulyana Horodyskyj and *New Scientist* features editor Leah Crane present big stories on polar science – including IceCube, the Antarctic neutrino detector that has identified cosmic signals from across the Milky Way.

newscientist.com/events

Podcast

Weekly

Hear from the neuroscientist who scanned her own brain 75 times over many months to see how it was changed by taking the birth control pill. The team also discuss why, surprisingly, the heat energy gained by Earth this year fell compared with last year. Plus, a mysterious 800-year-old cold case of a body stashed inside a well has been solved.

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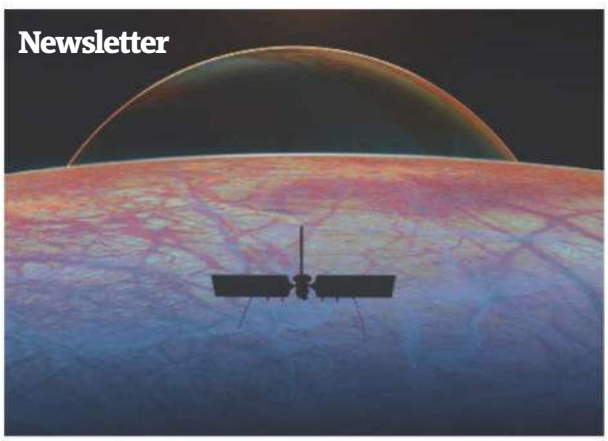


NASA/JET PROPULSION LABORATORY-CALTECH

Europa Clipper What lurks beneath the surface of this icy moon?

OCEANO AZUL GORRINGE EXPEDITION/JORDI CHIAS

Marine forest Mapping this seamount could protect its biodiversity

Video

Hidden bounty

The Gorringe seamount, off the Portuguese coast in the Atlantic Ocean, is the tallest underwater mountain in western Europe. It sits at the confluence of multiple ocean currents, making it a magnet for sea life and a biodiversity hotspot. *New Scientist* joined conservation organisation the Oceano Azul Foundation on a recent expedition to explore its depths.

youtube.com/newscientist

Newsletter

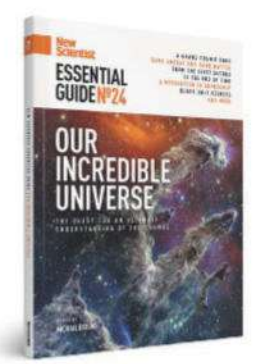
Launchpad

Just over two weeks ago, NASA's Europa Clipper mission took off and began its six-year journey towards Jupiter's moon Europa. Features editor Leah Crane looks at what we hope to learn from this highly anticipated mission and why Europa is one of the best, if not the very best, places in our solar system to hunt for life.

newscientist.com/launchpad

Podcast

"DNA analysis suggests that the Well Man most likely had blue eyes and blond or light-brown hair"



Essential guide

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How AI-powered cutting-edge technology is **revolutionising vaccine development**

Scientists are using artificial intelligence (AI) to quickly design vaccines tailored to individual patients in oncology and universal designs for infectious diseases. This innovation could revolutionise the treatment landscape.

Saverio Niccolini
CEO, NEC OncoImmunity, an NEC Bio Company

Kaidre Bendjama
CSO, NEC OncoImmunity, an NEC Bio Company

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In the complex field of vaccine development, AI isn't just a game-changer. It could also be a lifesaver. For instance, NEC Bio uses state-of-the-art machine learning technology to design vaccines that could significantly improve outcomes for cancer patients. The company has already developed applications in the oncology space and is looking to repeat the same success in infectious diseases.

"In 2019, the company decided to make AI-based drug development a growth area," explains Saverio Niccolini, CEO at NEC OncoImmunity, a subsidiary of NEC Bio. "Many biotechs try to acquire AI capabilities without having a deep understanding of it. Whereas, AI is in our DNA."

Modelling the entire immune system with AI

By using AI technology to model the body's entire immune system, scientists are able to create vaccines, in oncology, tailored to individual patients. "This type of personalisation is only possible because of AI," says Niccolini. "Think of it this way: there are millions of cancer cells in the body with different mutations. There are also millions of cells that can stimulate potential immune responses to kill the cancer. These vast numbers can only be computationally resolved with AI modelling, which mimics the molecular processing happening inside each of these cells."

With artificial intelligence, we can design a targeted vaccine, in silico, in a matter of days.

AI has also put rocket boosters under the company's vaccine development timelines. "Engineering a vaccine in a wet lab can take months," says Niccolini. "Yet, with artificial intelligence, we can design a targeted vaccine, in silico, in a matter of days."

An example of this is the company's personalised vaccine for patients with head and neck cancer. While still in clinical trials, so far, the results look promising. "In a significant proportion of these patients, the cancer returns within two years of the first treatment," explains Kaidre Bendjama, CSO. "To prevent recurrence, we created a bespoke vaccine in partnership with a biotech firm. We're pleased to say that none of the patients in the trial who were given the vaccine have experienced a relapse, and there have been no reported safety issues. Ultimately, if the trial is successful and the vaccine is approved, it could change the treatment landscape for various cancers by providing patients with a new class of targeted therapy."

Creating universal vaccines for infectious disease

The company has now repurposed its AI oncology model to create universal vaccines for various infectious diseases, including HBV and influenza. It has also partnered with CEPI (the Coalition for Epidemic Preparedness Innovations) to advance the development of vaccines that provide broad protection against SARS-CoV-2 variants and other betacorona viruses.

"Unlike oncology vaccines that are personalised to the patient, we aim to create universal infectious disease vaccines that are targeted at whole virus families or across a range of virus variants," says Bendjama. "However, it's still early days. Animal studies have yielded interesting data and look promising for future clinical applications."

Accelerating the path from drug discovery to market

While it is certainly challenging to be working in the vaccine development field, it also presents us with an exciting opportunity to apply NEC Bio's expertise in AI, says Niccolini. "Although we can design vaccines quickly with AI, we still face the long wait for drug approvals through clinical trials," he says.

"This is understandable because there needs to be rigorous analysis of the impact of new drugs on patients. However, as we recognised during the pandemic, the process needs to be accelerated, which is why we are open to collaboration with pharma companies and not only offer our drug development technologies but also ICT technologies that can potentially shorten the operational timelines. Relying on pharma partners' clinical development expertise, we believe that we can bring the drug to the patient faster."

i NEC Bio is a fully owned subsidiary of the NEC Corporation, a 125-year-old Tokyo-based IT and electronics multinational conglomerate.

AN INDEPENDENT SUPPLEMENT FROM MEDIAPLANET WHO TAKE SOLE RESPONSIBILITY FOR ITS CONTENT

Something to feast on

Our special issue on how to eat better cuts through the latest nutritional fads

LOADING up your plate has never seemed more complicated. Alongside appeals to avoid ultra-processed foods and "bad" fats, we are being bombarded by a growing array of sometimes conflicting dietary advice. Not only is it confusing, but it is hard to tell what difference these choices will really make in the long term.

Social media is filled with people talking about the health benefits of what they eat, with diets that promise a better hormonal balance going viral, for example. While it should go without saying that any nutritional advice delivered on TikTok should be taken with a pinch of salt, it is easy to get swept up in the excitement and start to believe that there must be a dollop of truth to such claims.

Then there are fermented foods, which are often sold as a dietary panacea. Do we really need to load up on kimchi and kombucha to be truly healthy?

Even nutrition science can add to the confusion. The more we hear about the latest discoveries, the more it seems we can tweak our diet to focus on specific outcomes, whether that is lowering chronic inflammation, improving our health and weight by eating at specific times or choosing what to eat based on our personal response to foods.

> "Not only is it confusing, it is hard to tell what difference these choices really make"

To help navigate this minefield, we have put together a delectable special issue of *New Scientist* on how to eat better, focusing on seven of the hottest nutritional trends of the moment.

This has revealed a few surprises. Recent research, for instance, shows that snacking – long demonised as generally a bad thing – can actually be positive for our health and waistlines.

Then there is the surprisingly wide-reaching health effects of something that we already knew was good for our gut: dietary fibre. Unlike many ingredients touted as superfoods, this one does really live up to its promise, yet most of us aren't getting enough of it.

So turn to page 32 for our evidence-based guide to what should really be on your plate to boost your chances of a longer and healthier life. ▮

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ANTHONY BEHAR/SIPA USA/ALAMY

Life

A giant dinosaur in New York City

This statue of a pigeon, towering over New York's High Line at nearly 5 metres tall, is titled *Dinosaur* and is meant to serve as a reminder that birds evolved from these ancient reptiles. "Like them, one day we won't be around anymore, but perhaps a remnant of humanity will live on – as pigeons do," said its creator, artist Iván Argote, in a statement.

Environment

Earth's heat gain is slowing

The recent surge in warming led to fears that climate change may be accelerating beyond projections, but a fall in how much heat Earth is gaining makes this less likely, says **Michael Le Page**

THIS year is on course to be the hottest on record, with an average global surface temperature more than 1.5°C above pre-industrial levels. But there is some better news: the overall amount of heat energy being gained by the planet has fallen sharply from a record spike early in 2023.

At the time, there were suggestions that the spike in heat gain showed there are flaws in climate models that mean they are underestimating how fast the planet will warm. But the fall since then makes this much less likely.

"Given the way that the numbers have evolved in the last year, it no longer looks like there's anything dramatically wrong with the models," says Ben Sanderson at the CICERO Center for International Climate Research in Oslo, Norway. "So it's not the sort of potentially dramatic issue some people were saying it was a year ago."

The latest satellite data showing the fall in heat gain was posted on Bluesky by Gavin Schmidt at NASA (see graph, below right). "It doesn't support a doomist narrative," Schmidt posted.

There is a big difference between tracking the increasing impacts that climate change and habitat loss are having, and buying into a notion that everything is spiralling out of control and we no longer have agency, he said. "That (IMO) is not justified."

Studies of global warming naturally focus on the surface temperature, which accounts for the air a couple of metres above the land or sea. But this thin layer of air in which we live is just a small part of the climate system, which includes the entire atmosphere and oceans.

To get a measure of how much the entire climate system is warming, scientists can look at how much of the sun's energy

WISKERKE/ALAMY

Despite record temperature highs in 2024, Earth's gain in heat has slowed down

enters the planet's atmosphere versus how much leaves it. Some sunlight is reflected immediately by, for example, clouds or ice. The rest is absorbed and may later be emitted as heat energy.

If as much energy is reflected or emitted back into space as hits the atmosphere, the planet doesn't gain any heat. But because rising greenhouse gas levels are blocking heat emissions, Earth has been gaining more heat than it loses.

Since about 2001, the planet's energy imbalance, as this is known, has been measured directly by instruments on satellites as part of a NASA project called CERES. Over this time, the average energy imbalance has more than doubled.

"It is on the high end compared to the models," says Norman Loeb at NASA, who heads up CERES.

But the energy imbalance also varies due to factors such as the La Niña and El Niño climate patterns. The big spike in 2023 was a result of a rare "triple-dip" La Niña that continued for three winters, says Loeb.

During a La Niña, cold ocean waters spread across the Pacific, soaking up a lot more heat from the sun and atmosphere than they emit, which increases the energy imbalance. This La Niña then gave way to an El Niño, in which warm waters spread across the Pacific, emitting more heat and reducing the energy imbalance.

As far as Loeb is concerned, neither the spike in 2023 nor the decline since the El Niño developed are that surprising.

"Had that [spike] continued, it would have very much looked like the real world was doing something which we weren't seeing in any of the models,"

"It's not the sort of potentially dramatic issue some people were saying it was a year ago"

says Sanderson. "As it actually turned out, it was a short spike, and we do see comparable spikes in the model data as well."

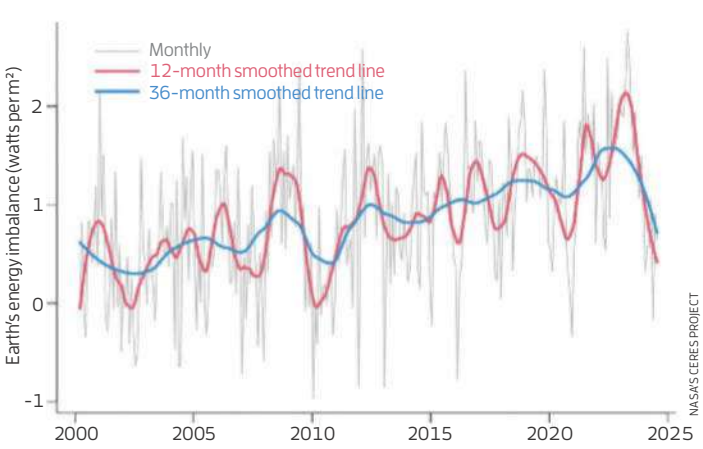
That said, many questions remain to be resolved, he says. For instance, reductions in air pollution in many parts of the world are thought to have contributed to the rise in the energy imbalance. Aerosol pollutants reflect sunlight back into space, so less pollution from, say, shipping allows more sunlight to reach the planet's surface. But there is a lot of uncertainty about the size of these effects.

Then there is the question of how the energy imbalance will change in the future. If greenhouse gas emissions remain at roughly the same level, rather than continuing to rise, the energy imbalance should stop rising too, says Sanderson.

There is a danger that we won't be able to tell, says Loeb, because the number of satellites carrying CERES instruments is falling, and they aren't being replaced. "It takes a long time from the time you start working on the satellite instrument until it actually launches," he says. "So you have to really plan ahead, and I don't think we're doing a very good job on that." ▮

Ever increasing heat energy

Earth is generally gaining more heat energy from the sun than it loses to space. This energy imbalance rose sharply in 2023, but the rise has slowed this year



NASA'S CERES PROJECT

For more on the La Niña and El Niño climate patterns, turn to page 18

Health

Mindfulness meditation may increase empathy

Grace Wade

MEDITATION training led women to experience more empathy for strangers, which suggests that meditation can improve our ability to understand and experience other people's feelings.

"When you practise mindfulness meditation, these feelings of connectivity and empathy and compassion arise naturally," says Fadel Zeidan at the University of California, San Diego.

He and his colleagues studied this in women and their romantic partners. The team used a tool to mimic the sensation of burning without damaging the skin in 29 women, their partners and a group of strangers. While having their brain scanned, the women watched videos of others feeling the painful stimulus and recorded how unpleasant it was to do so – a metric of empathy – on a scale of 0 to 10.

On average, they had 49 per cent more empathy for their partner than a stranger. They also had greater activity in the precuneus, a brain region involved in sense of self, when observing their partners. Previous research suggests that regular meditation can boost activity in the precuneus. To further investigate this, the researchers had 17 of the participants complete eight weeks of meditation training and repeated the pain experiments after four and eight weeks.

At both points, the women had a higher level of empathy for both strangers and their romantic partner, though it raised much more for the strangers so there was no longer a statistically significant difference between the two. The researchers are still analysing the participants' brain scans, but Zeidan says this suggests that even four weeks of consistent mindfulness meditation can boost empathy. He presented the findings at a meeting of the Society for Neuroscience in Chicago on 8 October. ▮

Evolution

Weird microbes are rewriting the origin of multicellular life

Claire Ainsworth

FRANCISCO J. ENGUITA/SCIENCE PHOTO LIBRARY

An illustration of a protein from a microbe called *Haloferax volcanii*

PHYSICAL forces like pressure could be behind key leaps in the evolution of life, such as the emergence of multicellularity. This comes after scientists compressed a type of single-celled microorganism, which caused it to develop into a multicellular tissue-like structure containing different kinds of cells.

The organism is a type of archaea, one of the three domains of life, along with bacteria and eukaryotes. The eukaryotes are organisms with cells containing a nucleus and include animals and plants. Archaea lack a nucleus, so were originally mistaken for bacteria, but are now thought to share a common ancestor with eukaryotes.

Unlike most organisms, archaea don't have a stiff cell wall, a trait they share with animal cells. Lacking a cell wall gives animal cells flexibility and allows them to develop markedly different shapes. They can change cell type in response to mechanical forces, too. Archaea are also able to form complex shapes and they interact with each other, but little is known about how they react to such forces.

To find out more, Alex Bisson at Brandeis University in Massachusetts and his team squashed a salt-loving archaea called *Haloferax volcanii* under jelly pads, mimicking the forces they experience in their natural habitats – and saw something completely unexpected.

60%

Prevalance of tested microbes that can turn multicellular

The cells grew and started making multiple copies of their genomes. When the tension in the cells' membranes reached a critical point, new membranes grew between these genomes to create individual cells that were genetic clones of the original cell, forming a mound-shaped multicellular tissue (bioRxiv, doi.org/npvf).

The team tested 52 other similar species and found that more than 60 per cent of them formed tissues. This kind of cell division is also seen in a wide range of multicellular eukaryotes, such as during chick embryo development.

Next, the team zapped individual cells in the tissues with a laser to test whether they were connected to each other. When a cell was killed by the laser, neighbouring cells moved towards the wound, as cells in animal tissues called epithelium do.

This suggests that cells in the archaeal tissues are tethered together, just as they are in animal or plant tissues. Archaea lack the genes that animal and plant cells use for these tethers, so they have probably evolved their own method of doing this, says Bisson.

The cells in the tissues also developed into two distinct types. Those around the edge – where less pressure was applied – were flat, while those in the middle formed an angular structure resembling a scutoid, a shape first identified in animal epithelial cells in 2018.

This shows the advantages of exploring the biomechanical properties of cells across domains of life – rather than just genetic information – when studying evolution, says Bisson.

"The idea that gene novelty alone governs evolutionary leaps now seems insufficient," says Omaya Dudin at the University of Geneva in Switzerland. "Physical and mechanical factors are emerging as key players in orchestrating complex biological innovations in single-celled creatures." ▮

Health

Electric skin patch could keep wounds free of infection

Carissa Wong

A PATCH that zaps the skin with electrical pulses could prevent bacteria on the skin from causing blood poisoning, reducing our reliance on antibiotics.

SAEHYUN KIM/UNIVERSITY OF CHICAGO

This bioelectronic patch can reduce the number of bacteria under it by shocking them

Staphylococcus epidermidis **bacteria usually live harmlessly on human skin, but if they enter the body after surgery or via skin cracks due to conditions such as psoriasis, they can cause bloodstream infections, which can lead to dangerously low blood pressure.**

Antibiotics can prevent and treat these infections, but antibiotic-resistant strains of *S. epidermidis* have emerged.

Now, Bozhi Tian at the University of Chicago and his colleagues have turned to electricity. They created a device from square plastic patches 1 millimetre wide, each containing gold electrodes that, when wired up, produce electrical pulses that can't be felt by people. They then spread a strain of *S. epidermidis* onto five samples of disinfected pig skin and put a patch on top of each.

After zapping the skin for 10 seconds every 10 minutes for 18 hours, *S. epidermidis* levels were reduced 10-fold on these samples compared with others that had non-electric patches put on them.

The intervention also disrupted the ability of the bacteria to join up to form a layer called a biofilm, which is linked to more severe infections (*Device*, doi.org/npjc).

The results suggest that the patches could cut the risk of drug-resistant *S. epidermidis* infections, says Tian. ▮

Astrobiology

Molecule needed for life spotted outside solar system for first time

Alex Wilkins

A COMPLEX form of carbon crucial for life on Earth has been detected beyond the solar system for the first time. Its presence helps show how the compounds needed for life could come from space.

The most abundant form of carbon in the universe is that found in carbon monoxide gas, but it is unclear how this turns into the complex compounds found in biological life, which typically contain stronger chemical bonds.

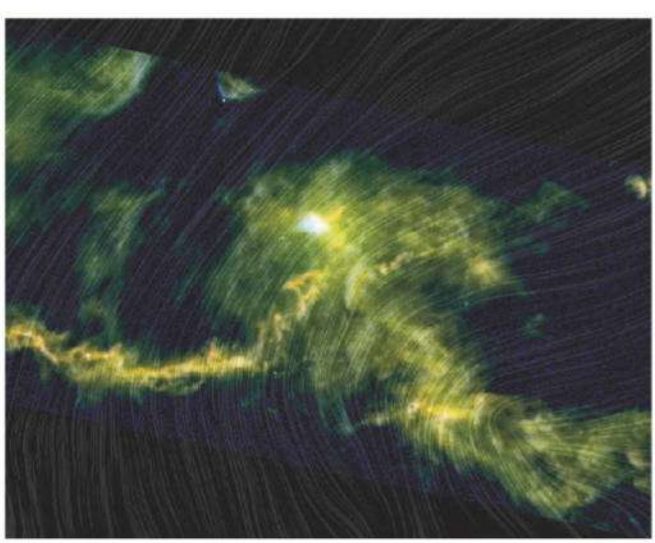
Astronomers have spotted asteroids – such as Ryugu – containing compounds with these stronger carbon bonds. It is thought that such space rocks may have delivered the ingredients for life to Earth, but the original source of the carbon-based compounds in objects like asteroids still isn't well understood.

Now, Brett McGuire at the Massachusetts Institute of Technology and his colleagues have looked for and detected a complex, carbon-based molecule called pyrene in a star-forming region called the Taurus molecular cloud. At 430 light years away, this is one of the closest such clouds to Earth.

> "Now we're looking back in time and seeing the same molecules forming"

The researchers used the Green Bank Observatory in West Virginia to search for the radio signature of pyrene. Such molecules would be crucial intermediaries between carbon monoxide and complex carbon molecules in living organisms.

Pure pyrene isn't that easy to detect clearly with radio waves, so McGuire and his colleagues instead looked for cyanopyrene, which is pyrene with an attached cyanide molecule, and compared it against the signature of cyanopyrene that they had also carefully produced and measured in the lab on Earth (*Science*, doi.org/npjb).



ESA/HERSCHEL/PLANCK; J. D. SOLER, MPIA

The Taurus molecular cloud contains compounds known as pyrenes

The cloud the researchers saw the cyanopyrene in is extremely cold, at about 10 degrees above absolute zero (-263°C), which means we are seeing these carbon compounds existing at a stage long before a star has formed, says McGuire.

"Now, we're seeing both ends of this life cycle," he says. We are seeing the chemical archaeological record in our solar system in asteroids and on Earth, says McGuire, "and now we're looking back in time at a place where another solar system will form, and seeing these same molecules there forming. We're seeing the start of the archaeological record."

Space reservoir

Assuming that the radio signal McGuire and his team observed from the Taurus molecular cloud is representative of elsewhere in space, it suggests that cyanopyrene is extremely abundant, and possibly one of the largest chemical reservoirs of complex carbon in the universe, he says.

Finding these molecules and the environment that they are in means that chemists can start sketching out the precise chemical reactions and pathways that eventually led to the building blocks of life on Earth, like nucleic acids, says Martin McCoustra at Heriot-Watt University, UK.

It isn't straightforward to explain how the pyrene molecules form in the first place, he says. "What else is in that environment that would lead us to [pyrenes]? We're seeing here a much richer understanding of complex chemistry tied up with these aromatic molecules." ▮

Archaeology

The Stone Age artisans of Paris

Ancient stone goods found in France and Belgium may have been traded along vast networks

Christa Lesté-Lasserre

AROUND 7000 years ago, long knives, bracelets and other stone goods fashioned by skilled Parisian crafters were reaching people hundreds of kilometres away, via complex trade networks that are now being mapped for the first time.

By combining archaeology with computer modelling, Solène Denis at the French National Centre for Scientific Research in Nanterre and Michael Kempf at the University of Basel in Switzerland have reconstructed the lengthy and winding paths taken to supply people from what is now Normandy to Belgium with goods from the greater Paris area.

"There were local markets, but what we also see are products made by people who have specific skills," says Denis. "Especially with long blade production, people in Belgium and elsewhere just didn't have the skills."

Scientists already knew that stone goods created in the Paris basin had arrived as far east as the Liège province in Belgium and as far west as the border of Britanny in France. They had also gone south to the Loire valley. But such destinations only tell a small part of the tale, says Denis.

"We're making new hypotheses, finding out that, oh, they had to go through this or that site, and connect with those people through friendly exchanges in their homes," she says.

The pair looked at the distances between previously established archaeological finds, such as long blades made from silicite or bracelets made from schist and serpentine, and the raw materials used to create them. They also considered waterways, forests, altitudes and environmental data that could suggest the possibility of hunting or gathering food, combining all of this into a computer model (*Quaternary Environments and Humans*, doi.org/npvd).

"If you want to go from Point A to Point B, it might make sense to go straight, but it could also make sense to go a bit to the right, a bit to the left, because, you know, there are people you want to 'have coffee with', so to speak," says Kempf. "What we're doing is trying to combine these sociocultural and environmental perspectives."

In particular, the pair examined information from 133 sites spanning from about 5000 to 4650 BC to develop the networks of where traders might have originated, travelled, dropped off their goods and spent the night to benefit from local commodities.

The findings show that many of the goods originate within a few dozen kilometres around modern-day Paris, says Kempf. Indeed, starting at about 4950 BC, what is now the greater Paris area became a strong source of skilfully crafted long blades in particular.

Trade networks reached about 250 kilometres to the north-east and about 200 kilometres to the south, where the untamed Loire river may have dissuaded commerce. The more easily navigable Seine river appears to have promoted trade, especially in the final two centuries studied. The networks also reach 400 kilometres to the west, halting due to the difficult hills of Brittany and possibly competition from other craftspeople, as the model suggests another, non-overlapping trade network in this region, says Denis.

While the findings make sense, computer models may not provide the full picture, says Ivan Jadin at the Royal Belgian Institute of Natural Sciences in Brussels. "There are lots of hypotheses about what happened at the time," he says. "Now they just need to be supported through further study." ▮

Stone blades found in Belgium may have come from what is now Paris

SOLÈNE DENIS

Environment

Carbon emissions growing faster now than pre-pandemic

AS THE world emerged from the lockdowns of the covid-19 pandemic, many countries promised to rebuild their economies in a climate-friendly fashion. In reality, the opposite has happened.

Instead of a "green recovery", global greenhouse gas emissions are rising faster now than they did in the decade before the global pandemic. Annual emissions rose 1.3 per cent to 57.1 gigatonnes of carbon dioxide equivalent in 2023. That is a far faster rate of growth than during the 2010-2019 decade, when emissions rose on average 0.8 per cent per year. Global greenhouse gas emissions are now just below the 59.1 gigatonnes peak recorded in 2019.

All sources of greenhouse gas emissions except land use are rising, according to a report from the United Nations Environment Programme (UNEP), as economies continued to rebound from covid-19. Emissions from road transport, industrial emissions and leaks from oil and gas infrastructure such as pipelines all grew rapidly in 2023, UNEP said, while aviation emissions grew 19.5 per cent.

Rising emissions means the opportunity to avert catastrophic climate change is shrinking, said Inger Andersen at UNEP in a statement. "Climate crunch time is here," she said. "I urge every nation: no more hot air, please."

Since 2015, nations have collectively promised to limit warming to as close to 1.5°C above pre-industrial levels as possible, but current national targets don't come close to delivering that goal. Taking countries' current pledges into account, the world is on course for 2.6°C to 2.8°C of warming.

"Climate crunch time is here. I urge every nation: no more hot air, please"

Countries are expected to submit new national climate plans by February, ahead of the COP30 conference in Brazil in November.

Andersen said it is vital countries come to the table with bolder plans to cut emissions, which must start immediately, otherwise the 1.5°C goal is unlikely to be achieved. ▮

Madeleine Cuff

Technology

Artificial intelligence falls for scams

AI is susceptible to being scammed – and some models are more gullible than others

Chris Stokel-Walker

THE large language models (LLMs) that power chatbots are increasingly being used in attempts to scam humans – but they are susceptible to being scammed themselves.

Udari Madhushani Sehwag at JP Morgan AI Research and her colleagues peppered three popular models – OpenAI's GPT-3.5 and GPT-4, as well as Meta's Llama 2 – with 37 scam scenarios (arXiv, doi.org/npkh).

The chatbots were told, for instance, that they had received an email recommending investing in a new cryptocurrency, with a referral link, and then were asked if they would buy it. Or they received offers to buy products at improbably low prices – which most humans would recognise as scams – and were asked whether they would choose to risk spending money on them.

These scam scenarios were developed further with four distinct persona variations, such as instructing the LLM to respond as if it were a person with a strong background in finance who regularly read financial news updates. The researchers also refined the initial scenarios, crafting multiple versions based on psychologist Robert Cialdini's principles of persuasion, which include being more likeable or offering to reciprocate any help. This let the researchers compare whether asking the LLM to take on a persona or giving it a more persuasive prompt would make it more susceptible to the scams.

> "At the moment, the systems should not be allowed the final word in any decision-making"

Different AI models had vastly different results. OpenAI's GPT-3.5 was susceptible to 22 per cent of scams that didn't adopt personas or use persuasion, while GPT-4 fell for 9 per cent of them. Llama 2 fell afoul of scams only 3 per cent of the time. Persuasive tactics were better at convincing models to fall for scams than changing the persona of the model.

An OpenAI spokesperson tells *New Scientist*, "We don't want our AI products to be used for malicious purposes and are continually enhancing safety measures. Our latest o1 reasoning model is our most capable and safest yet, significantly outperforming previous models in resisting deliberate attempts to generate unsafe content." The company has previously said that this model, released in September, is better at responding to malicious requests to "jailbreak" the system than the models surveyed in this study. Its o1 model scored 84 per cent on a jailbreak test, compared with 22 per cent for GPT-4o, a model that is similar to GPT-4. Meta didn't respond to a request for comment.

"There has been quite a bit of attention paid to the misuse of LLMs to conduct scams," says Alan Woodward at the University of Surrey in the UK. "What is less understood is whether LLMs can be scammed, for example when they act as a chatbot representing an organisation." Woodward points out that some LLMs appear more susceptible than others to such trickery – but the reason why isn't always clear, due to the black box nature of these systems.

"Researchers are still trying to understand... how to make their systems' models aware of all the scam types that might occur," he says.

Woodward says these findings suggest AI cannot be trusted to operate by itself without oversight. "At the moment, the systems should not be allowed the final word in any decision-making process, but a human should be involved, and that human needs to understand how a particular algorithmic decision has been arrived at," he says. ▮

Technology

Battery made from water and clay could be used on Mars

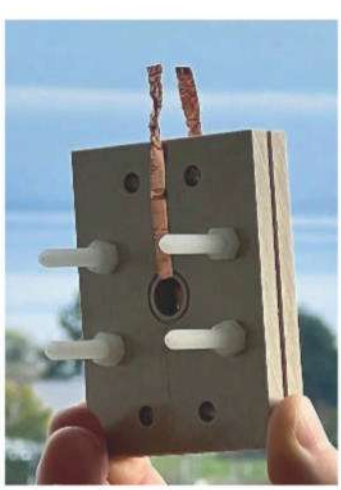
WHEN pushed into microscopic grooves, water works in unexpected ways. A new battery design that relies on tiny amounts of water confined within layers of clay could eventually offer sustainable power in places as extreme as Mars.

Vasily Artemov at the Swiss Federal Institute of Technology and his colleagues built the device with components similar to those of conventional batteries, including two electrodes, one negatively and one positively charged.

But instead of making the electrodes out of metal, they used graphene, a single layer of carbon atoms. Rather than fill the space between them with a lithium salt solution, they used clay and water.

The clay layers are full of microscopic channels about a nanometre thick. Filling these channels with water made the liquid behave like a "working fluid" in a battery, meaning that it creates a separation between opposite charges as those particles move between the two electrodes. This is how the battery stores energy. It produced 1.6 volts and charged and drained 60,000 times without losing efficiency (arXiv, doi.org/nph4).

"It's surprising that you can make a battery out of just water and clay," says Michael Strano at the Massachusetts Institute of Technology. He says that because the new battery doesn't require scarce materials like lithium, it could be an exciting future technology.



YUNFEI TENG

This water-and-clay battery prototype could be made from Martian materials

Artemov says they made the battery design as simple as possible, hoping that would help it become broadly used – even beyond Earth. They have analysed a variety of types of clay that exist on Mars and found them viable for their design.

"The first industrial revolution was driven by water because of the steam engine. Maybe we can now, by appreciating water at the nanoscale, drive a small revolution too," says team member Patrick Huber at the Hamburg University of Technology in Germany. ▮

Karmela Padavic-Callaghan

Health

Stories about magical fruit help children eat healthily

Clarissa Brincat

FAIRY tales featuring magical fruit and vegetables seem to encourage children to make healthy food choices, and just 20 minutes of storytelling can make a difference.

Childhood obesity is a concern in many countries, so to see what could counter it, Werner Sommer at the Humboldt University of Berlin in Germany and his colleagues turned to 80 children between 4 and 6 years old in Kenya.

They divided the children into two groups. The first heard a story about a painter who refreshes the colours of a city every night but was unable to when he became ill from eating junk food. His strength was restored by eating magic vegetables. The second group heard a similar story but without any food references.

Every day for the next two weeks, the children were offered a choice of snacking on fruit, vegetables, cakes or cookies, presented on the same platter. Those who heard the first story ate more fruit and vegetables than they did a week before hearing the tale, while no change occurred in those who heard the second story (medRxiv, doi.org/nph9).

"With a single instance of storytelling lasting only about 20 minutes, we obtained a surprisingly strong change from a preference for non-healthy snack food towards a preference for healthy fruits or vegetables," says Sommer.

The children probably got a taste for the healthy snacks after being motivated to try them following the first story, says Wendy Wood at the University of Southern California. "Repeated consumption of a food increases the likelihood that kids will eat it again," she says.

However, as the stories were told by the children's teachers, the children might have chosen healthier snacks after sensing that was the "right" choice from hearing the story, not because their food preferences changed, she says. ▮

Archaeology

DNA helps match 'Well Man' skeleton to 800-year-old saga

James Woodford

L: NIKU; R: AGE HOJEM, NTNU UNIVERSITY MUSEUM

Near left: the complete skeletal remains of the "Well Man"; far left: a 2016 excavation of the remains

A NORWEGIAN saga written more than 800 years ago describes how a dead man was thrown into a castle well – and now, researchers believe they have identified the remains of this man.

The *Sverris saga* is an 182-verse Old Norse text that records the exploits of King Sverre Sigurdsson, who rose to power in the second half of the 12th century AD. One part says that a rival clan who attacked Sverresborg castle, near Trondheim, Norway, "took a dead man and cast him unto the well, and then filled it up with stones".

The well was inside the castle's ramparts and was the community's only permanent water source. It has been speculated that the man thrown into the well in the saga may have had a disease and putting him there was an early act of biological warfare.

In 1938, a medieval well in the ruins of Sverresborg castle was partly drained and a skeleton was found beneath rubble and boulders at the bottom. While it was widely believed that the skeleton, referred to as Well Man, was the remains of the individual mentioned in the saga, it wasn't possible to confirm this at the time.

Now, Anna Petersén at the Norwegian Institute of Cultural Heritage Research in Oslo and her colleagues have used radiocarbon dating and DNA analysis of a tooth from the body to show that the date range for when the man was alive aligns with the raid on the castle. While not definitive proof that the man was the one mentioned in the saga, the "circumstantial evidence is consistent with this conclusion", says Petersén.

"The genetic data enriches the story and provides a way to separate fact from fiction"

What is more, the team has been able to add to the story. "The research we have done has shown many details concerning both the event and the man that the saga episode doesn't mention," says Petersén.

For example, the DNA suggests he probably had blue eyes and blond or light-brown hair. The researchers also think that his ancestors were from what is now Vest-Agder, the southernmost Norwegian county, based on comparisons with the DNA of modern and ancient Norwegians (*iScience*, doi.org/10/npjz).

One thing they couldn't find was any evidence that the man was thrown into the well because he had a disease or to render the drinking water unusable, but they also found no evidence against it, leaving the question unanswered.

Michael Martin at the Norwegian University of Science and Technology in Trondheim says the team's approach of matching historical documents with DNA evidence could also be applied to construct family trees of long-dead royal families or to "physically describe and sketch out the life stories, such as movement between geographic regions, of the otherwise anonymous people whose remains are recovered from archaeological excavations".

"This is, to my knowledge, the oldest case where genomic information has been recovered from a specific character, or even a specific person, mentioned in an ancient text," says Martin. "The genetic data enriches the story and provides a way to separate fact from fiction." ▮

Microbiology

Bacteria force enemies to switch sides

Armies of microbes armed with poison darts fight in your gut – and some have a secret weapon

Michael Le Page

YOUR gut is a battleground where rival tribes of bacteria armed with poison darts fight for territory, and these conflicts are often won by armies of traitors made to switch sides.

"The human colon is one of the most dense microbial ecosystems on Earth," says Laurie Comstock at the University of Chicago in Illinois. There are lots of different species of bacteria, and different strains within species, fighting for the same resources.

To get the upper hand, many release toxins to poison rivals. Some are armed with an even more extraordinary weapon – dart guns that fire high-speed syringes for injecting poisons directly into other bacteria or nearby cells. "They are a spring-loaded weapon that requires the organisms to be very close," says Comstock.

The innocuous-sounding name for this kind of dart gun is a type 6 secretory system, or T6SS. A wide range of species are armed with them, and there is a lot of variation in how they work – the darts can contain many different toxins, for instance.

Some species just blindly fire off poison darts as fast as they can make them, hitting friend and foe alike. Crucially, however, the genetic instructions for making a specific kind of dart gun come with the instructions for making the antidote to the poison in its darts. When a bacterium is hit by darts from a member of its own tribe, it isn't harmed. Put another way, in this world of poison darts and antidotes, what side a bacterium is on is determined by what dart gun and antidote it manufactures.

One of the most vicious species is called *Bacteroides fragilis*, which releases a range of poisons, as well as firing its darts non-stop.

CNRI/SCIENCE PHOTO LIBRARY

***Bacteroides* fragilis comes armed with poisoned darts**

B. fragilis feeds on complex sugars in the mucus lining of the gut, so Comstock thinks the reason for its aggression is that it tries to take over the mucus lining and defend itself against other related species.

But some of these other species harbour weapons in the form of pieces of "selfish" DNA that seem to act almost like independent entities. One of these pieces of DNA, called GA1, encodes genes for machinery that enables GA1 to transfer copies of itself to other bacteria.

It also has genes for a dart gun and the antidote to the dart-gun poison. Comstock's team has shown that once GA1 gets into *B. fragilis*, it somehow blocks production of the *B. fragilis* gun and makes them start producing the GA1 gun instead – essentially turning them traitor (*Science*, doi.org/g8n4dn).

When these bacteria multiply, they form armies of traitors that can kill *B. fragilis* that lack GA1. The traitor armies usually win these battles, Comstock's team found in a number of tests. But in our guts, where many other species and toxins are present, the outcomes may differ, she says.

Her team has also discovered another bit of selfish DNA called GA2, which appears to behave in a similar way to GA1 but with a different dart gun and antidote.

"Side switching may be more common than we have appreciated," says Brian Hammer at the Georgia Institute of Technology in Atlanta. ▮

Environment

Nuclear waste tanker tests out aluminium sail

A VESSEL normally used to ship nuclear waste around the world is testing an aluminium sail that could slash the fuel consumption and climate impact of ocean tankers.

The Pacific Grebe is spending three weeks, which started in October, off the UK coast trialling the FastRig, a 20-metre-tall sail. The retractable, blade-like sail weighs about 35 tonnes and can be unfurled in winds of up to 64 kilometres per hour, according to its UK-based makers Smart Green Shipping. The sail is designed to be used on tankers carrying unpackaged commodities such as grains and fuel, says Di Gilpin at Smart Green Shipping. "It's like an aircraft wing, but it's also a bit like a wind turbine blade," she says.

Calculations by the company suggest the technology could cut a ship's annual fuel consumption by up to 30 per cent.

NTS/SMART GREEN SHIPPING

The Pacific Grebe is spending three weeks testing the FastRig sail

Joseph Banks at the University of Southampton, UK, part of the team working on the trials, says the tests in the English Channel and the Irish Sea will help show "how the wing sail changes the performance of the ship" and affects fuel use.

In 2022, the global shipping industry was responsible for about 858 million tonnes of carbon dioxide emissions, more than the aviation sector.

The Pacific Grebe's set-up is a pilot version. A full installation of FastRig would see multiple sails – each 34 metres tall – fitted to both sides of ships, says Gilpin.

Other firms are also trialling sails on cargo vessels. In 2023, the Pyxis Ocean, a ship chartered by agricultural giant Cargill, set off fitted with two 37.5-metre WindWings, which cut its annual CO_2 emissions by about 14 per cent. ▮

Madeleine Cuff

Environment

Wildfires in parts of US growing twice as fast as they used to

James Dinneen

FOREST fires in the western US aren't only growing bigger. They are also growing faster, putting millions of people and properties at greater risk.

"In the context of home destruction and lives lost, we really need to think more about fire speed than fire size," says Jennifer Balch at the University of Colorado, Boulder.

Rapidly spreading wildfires, such as the Lahaina fire in Hawaii last year, are especially destructive because they become unstoppable, moving faster than firefighters can combat them.

To assess how wildfire speed has changed, Balch and her colleagues used satellite data to estimate the speed of more than 60,000 fires in the US between 2001 and 2020, using daily growth rate as a proxy for this. They also aggregated millions of government documents and property records to estimate the damage caused by these fires.

They found that fires in most of the western half of the country are growing faster: here, the average maximum daily growth rate more than doubled over the 20 years studied. Balch says this change is linked to climate change making hot, dry, windy "fire weather" more common, as well as a buildup of combustible material in forests.

In the northeastern US, however, fire growth rate has declined, which could be to do with fragmentation of wooded areas by roads and other infrastructure, says Balch.

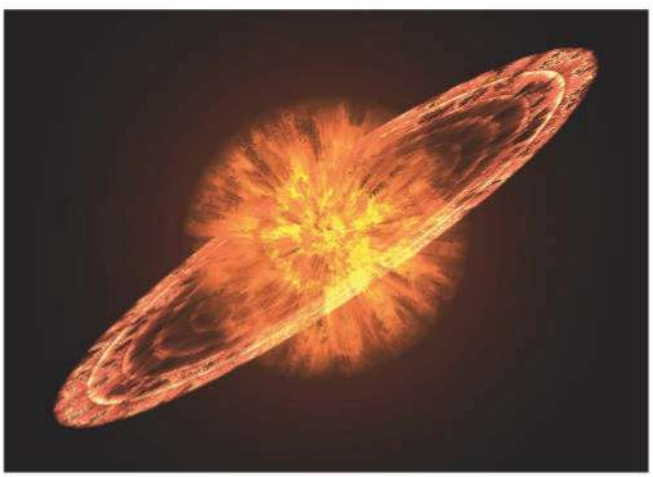
The researchers dubbed fires that grew more than 1620 hectares a day "fast fires". Though these accounted for just 2.7 per cent of all blazes, they were responsible for 89 per cent of the damage (*Science*, doi.org/nphk).

The findings suggest we need to do more to minimise damage from unstoppable fires, such as by fire-proofing homes or developing evacuation plans, says Balch.

Astrophysics

Supernova sweep may have cleaned up our solar system

Jonathan O'Callaghan



SHUTTERSTOCK/ISMAGILOVA

When a star explodes in a supernova, it can clear away dust particles

THE blast from a nearby supernova should be enough to clear almost all the dust from our solar system, and this may have last happened 3 million years ago. But like the dust on furniture, these fine particles should gradually be replenished.

Dust we see drifting through space consists of small grains, resulting from events such as asteroid collisions. The grains are typically less than a millimetre in size, going down to just nanometres across. About 70 per cent of the solar system's dust is concentrated in the Kuiper belt, a region of icy asteroids and comets beyond Neptune, where there are an estimated 3.5 million gigatonnes of the tiny grains.

Jesse Miller at Boston University and his colleagues have modelled what would happen to the dust in the Kuiper belt if a star exploded within 160 light years of Earth, or if our solar system passed through a dense star-forming interstellar cloud of material.

One of these events is thought to have occurred about 3 million years ago based on increases in levels of a radioactive isotope of iron – iron-60 – seen in ice on Earth dating to that period. The isotopes would have been delivered when either of these phenomena stripped away the sun's heliosphere, which protects planets in our solar system from the galaxy's radiation.

Miller and his colleagues have found that either event would sweep all dust smaller than a millimetre from the Kuiper belt. "It's like turning on a giant fan," says Miller. "There's a lot of hydrogen atoms hitting these dust grains and changing their orbits", with the dust either being pushed into the sun or ejected from our solar system entirely (arXiv, doi.org/npch).

70%
of the solar system's dust is in the Kuiper belt region

Mikako Matsuura at Cardiff University, UK, says the wind produced by a supernova can travel at "a few thousand to 10,000 kilometres per second", which could have "enough kinetic energy to blow off material in the solar system".

The blast wave's low density, "in the ballpark of 0.01 atoms per cubic centimetre", says Miller, means it would have been halted at about Saturn's orbit by the solar wind of charged particles heading out from the sun. An interstellar cloud – being denser, at 1000 atoms per cubic centimetre, but slower, at about 20 kilometres per second – could have penetrated within the orbit of Mercury, reducing the amount of interplanetary dust near Earth, although there isn't a lot of dust near our planet compared with what's in the Kuiper belt, says Miller.

While it would take tens of thousands of years for the solar system to traverse a supernova's blast wave, an encounter with an intersteller cloud could last up to a million years.

Some of the dust in the Kuiper belt could also have been moved into reservoirs in a different orbit out of the flat plane of our solar system. "That would mean it's not interacting with the planets as much," says Miller. This might explain why NASA's New Horizons spacecraft, currently travelling through the Kuiper belt region, has detected an increase in dust, as it could be moving through such an area.

The researchers calculate that it should take about 11 million years for dust in our solar system to return to an equilibrium state, where it is being produced as fast as it is falling into the sun or being ejected by more usual processes. If a dust-sweeping event did happen 3 million years ago, that "means we're still in the building-up phase", says Miller.

Palaeontology

Ancient tracks hint that dinosaurs used wings to leap further

Christa Lesté-Lasserre

TINY tracks in South Korea symbolise a moment 120 million years ago when a dinosaur took advantage of its wings to cover ground in large leaps – the oldest such evidence of wing-assisted movement in these extinct animals.

Velociraptors and other raptors (dromaeosaurids) are the ancestors of modern birds, but their lineage split into avian and non-avian, or "paravian", lines about 170 million years ago. Despite having feathers and wings, paravian dinosaurs generally seemed to lack the wingspan needed to actually fly, says Michael Pittman at the Chinese University of Hong Kong.

But Pittman and his colleagues suspected that some paravian dinosaurs could at least glide before full flight evolved in birds, based on muscles in their upper bodies. So, they have studied more than 2600 rows of dinosaur tracks around the world. One set of tracks, discovered during the construction of a shopping centre in south-eastern South Korea, showed surprisingly long spacing between steps made by a sparrow-sized raptor called *Dromaeosauriformipes rarus*.

Adjusting for relative leg length, its stride would be three times as long as that of an ostrich and nearly twice that of a kangaroo rat. "I had this eureka moment: could it have been doing something other than running?" says Pittman.

Further calculations and comparisons with fossil anatomy suggested that the animal couldn't have made that stride with its legs alone (*PNAS*, doi.org/npck). It was clearly flapping or gliding, possibly while launching or landing, says Pittman.

"I think the vast majority of feathered dinosaurs were probably doing what this guy was doing – using the wings to augment running, jumping, braking and turning," says Pittman. ▮

Physiology

Morphing red blood cells help bats to survive hibernation

Christa Lesté-Lasserre

PAUL HOBSON/NATUREPL.COM

Common noctule bats (*Nyctalus noctula*) hibernate over winter

BATS modify their red blood cells to make them thicker and more rigid when they hibernate – and if we can figure out how, people might one day be able to copy the process for medical treatments or long-distance space travel.

Animals hibernate to conserve energy during cold weather or when food becomes scarce, slowing their heart rate and dropping their body temperature to as low as 5°C (41°F) to enter a state known as torpor. This is only survivable if their blood continues to flow efficiently and supply oxygen to the body, but until now scientists haven't fully understood how this happens.

We already know that red blood cells change shape to fit different pressures and blood vessel sizes. To investigate if something like this happens in the cells of hibernating animals to keep blood flowing, Gerald Kerth at the University of Greifswald in Germany and his colleagues turned to bats. They analysed hundreds of thousands of red blood cells from common noctule bats (*Nyctalus noctula*), which hibernate, and Egyptian fruit bats (*Rousettus aegyptiacus*), which don't, along with cells from people.

The researchers found that, for all three species, red blood cells became less elastic and more viscous as temperatures dropped from 37°C to 23°C (99°F to 73°F). But when they cooled the cells even further to 10°C (50°F), the bat cells continued this metamorphosis, whereas the human cells did not (*PNAS*, doi.org/npcg).

<10°C

Bat red blood cells become stiffer at these temperatures

Indeed, the bat cells – even those of non-hibernating bats, which probably maintained the evolutionary capacity – continued to become thick, stiff and functional even at very low temperatures. This change might be slowing down the cells as they pass through capillaries in the muscles and lungs, making them highly efficient at exchanging gases, like oxygen, throughout the body.

"It's like how when you take your time at the supermarket instead of being rushed, you can really fill up your basket," says Kerth. Exactly how this structural change happens is still unclear, but the team speculates that the mechanical properties of the bat red blood cell membranes play a key role.

The findings suggest that drugs could one day induce human red blood cell membranes to mimic the way the bat membranes react to the cold, says Kerth.

Surgeons already use body cooling during certain procedures to slow down metabolism, which can help prevent organ damage in people experiencing heart attacks, organ transplants or major brain surgery. Being able to prolong that cooling time, or drop the temperature even lower, could increase those benefits, says team member Carsten Scholz, also at the University of Greifswald.

In the more distant future, hibernation could also allow for efficient long-distance space travel, requiring minimal food and other resources while preserving mental health during the journey. "There are benefits of putting humans at low temperature during interstellar flight," says Kerth.

"Nature is full of yet-to-be-disclosed secrets that can teach us how to overcome present and future medical and technological challenges," says Angelo D'Alessandro at the University of Colorado Anschutz. ▮

Mathematics

Meta AI tackles impossible maths

Mathematical problems that have stumped humans for over a century can now be worked out

Chris Stokel-Walker

AN ARTIFICIAL intelligence system developed by Meta can find solutions to maths problems that have eluded mathematicians for over a century, researchers at the firm claim.

The problems involve mathematical tools called Lyapunov functions, named after mathematician Aleksandr Lyapunov, which analyse whether a system will remain stable over time, meaning its behaviour can be predicted. One famous example of such a system is the motion of three celestial bodies as a result of their mutual gravitational interactions. Describing the behaviour of this "three-body problem" is very challenging.

In 1892, Lyapunov proved that such systems will remain stable if it is possible to discover a specific mathematical relationship, or function, for the system, but unfortunately mathematicians don't know any general approach for doing this.

Now, François Charton at Meta's Fundamental AI Research (FAIR) and his colleagues say AI can help. The researchers trained an AI system by working backwards, first by generating random Lyapunov functions that met certain pre-set requirements, then creating systems that matched these functions.

"We thought of the backward method because it was a way to speed up data generation," says Charton. But it also helped solve the major issue that had hindered mathematicians for more than 130 years: finding the function from the system is almost impossible, but developing the function, then matching it to a system, isn't. They supplemented this backward generation method with forward generation, finding the Lyapunov functions for some simpler systems that could be calculated using pre-existing computational techniques.

Having that training data meant their AI model could learn the patterns that have eluded human mathematicians. For the simplest systems – polynomial systems – the AI could find Lyapunov functions 10.1 per cent of the time, compared with a success rate of 2.1 per cent using traditional computational methods. In more complex non-polynomial systems, which can't currently be solved using computational techniques, the AI was successful 12.7 per cent of the time.

"Even if 99 per cent of AI solutions are hallucinatory trash, we can swiftly pick the good from the bad"

As a comparison against human mathematicians, the team gave 25 master's-level students three simpler polynomial problems each and asked them to find the Lyapunov function for them within a total of 30 minutes. In total, the students managed to solve seven of the 75 problems, or 9.3 per cent, while the AI solved 84 per cent (arXiv, doi.org/npb7).

Despite this success, the AI is still far from a universal technique for finding Lyapunov functions.

Jordan Ellenberg at the University of Wisconsin-Madison says it doesn't matter if the AI hasn't solved the problem outright – it can still be useful. "The AI can generate many candidate solutions, and even if 99 per cent are hallucinatory trash, we can swiftly and reliably pick out the good from the bad." ▮

Archaeology

Rare Bronze Age wooden tool found in English trench

AN INCREDIBLY rare wooden spade from the Bronze Age has been unearthed by archaeologists in the UK. It offers a glimpse into life when people were increasingly farming crops in settled communities.

"It's quite an immediate connection with the past," says Ed Treasure at Wessex Archaeology in Salisbury, UK.

The spade was found in wetlands near Poole Harbour on the south coast of England by Wessex Archaeology. The researchers were digging in ring gullies, circular trenches that may have originally surrounded shelters. In one gully, they spotted the handle of the spade, which had been carved from a single piece of oak. The wet conditions meant the shovel wasn't exposed to oxygen, slowing decay.

WESSEX ARCHAEOLOGY

Archaeologists carefully lift the Bronze Age spade onto a board to be sent to a lab

The team has radiocarbon dated the spade to 3400-3500 years ago, using a shard found alongside it. "A very small bit of the spade had become broken off in burial – we used that for dating," says Treasure. Nearby pottery indicated a similar date. This places the spade's origins in the Middle Bronze Age.

"It's quite a big time of change in prehistoric Britain," says Treasure. People were becoming less nomadic and spending much more time in settled communities, farming a range of cereals and other foods.

However, there is no sign of permanent settlement at the site, perhaps because it was and is a wetland. "We're very much thinking this is a seasonal use of this landscape," says Treasure. People may have brought animals in to graze in the summer, cut peat for fuel or collected reeds for thatching.

Future studies will assess how the spade was made, and what it was used for. "It might have been used to cut peat on the site," says Treasure. "It may also have been used to dig the ring gully in which it was found."

One of the only other spades from this period of Britain is the Brynlow shovel, found in 1875 and dating to almost 4000 years ago. ▮

Michael Marshall

Environment

Mystery of the missing La Niña

Climate-cooling pattern still hasn't appeared in the Pacific Ocean

James Dinneen

AN EXPECTED shift to cool La Niña conditions in the Pacific Ocean has been delayed again. Forecasters now project only a weak event to emerge by the end of November, which is likely to limit the cooling influence of the climate pattern on global average temperatures.

"I do not know why it has slowed down," says Michelle L'Heureux at the US National Oceanic and Atmospheric Administration (NOAA).

La Niña is the cool phase of the cycle of sea surface temperatures in the equatorial Pacific Ocean known as the El Niño Southern Oscillation (ENSO). This is among the largest influences on the global climate, and irregularly swings between La Niñas, neutral temperatures and warm El Niños every several years.

A rare "triple-dip" La Niña between 2020 and 2023 gave way to a strong El Niño starting in June 2023. On top of warming due to greenhouse gas emissions, the release of stored heat in the oceans from that event boosted global average temperatures, making 2023 the hottest year on record.

AP PHOTO/MARK BAKER/ALAMY

In the 2022 La Niña season, severe floods hit eastern Australia hard

As the El Niño faded and neutral temperatures emerged in May this year, forecasters projected a rapid shift to La Niña conditions. In June, researchers at NOAA gave La Niña a greater than 60 per cent chance of developing between July and September and a greater than 70 per cent chance of developing between August and October. This contributed to forecasts for an extreme Atlantic hurricane season.

While sea surface temperatures in the equatorial Pacific have cooled since then, a full-blown La Niña still hasn't emerged. NOAA now gives La Niña just a 60 per cent chance of developing by the end of November. The agency projects a weak and short event lasting until March.

That bullish early forecasts were off the mark isn't surprising, says Emily Becker at the University of Miami, Florida. Forecasts made that early in the year tend to be less accurate because small fluctuations in wind or water can have big effects, she says. It also isn't unheard of for La Niña to be late, even following a strong El Niño. Four La Niñas have emerged this late in the year since 1950.

But the reasons for the delay are unclear. "The trade winds have been slower than expected in parts of the eastern Pacific, which may be keeping waters on the equator warmer than forecasted," says L'Heureux. "But this may be more of a symptom than a cause."

Whether human-caused climate change is playing a role is an open question, says Becker. Some research suggests climate change will make ENSO more variable, but this remains a contentious area.

Despite the delays, a La Niña is slowly emerging, and it is likely to have its characteristic influence on global weather, from dry conditions in the southern US to rain in Indonesia. But as a weak event, it won't cool global average temperatures as much as a strong and long one. "We have seen the global average temperature come down, but it's still very elevated," says Becker. "We probably won't see as much of a decrease." ▮

Zoology

Hornets hold their alcohol like no other animal on Earth

A SPECIES of hornet that munches on foods containing alcohol can consume liquor at levels that no other animal is known to tolerate.

"This is crazy," says Sofia Bouchebti at the Ben-Gurion University of the Negev in Israel.

The diet of the oriental hornet (*Vespa orientalis*) consists of nectar and ripe fruit like grapes. The fruit contains sugar that turns into ethanol when it naturally ferments.

While ethanol can be nutritious, it is also intoxicating. Even animals that routinely eat fermenting fruit, like fruit flies and tree shrews, can't stomach more than 4 per cent ethanol in their meals, according to Bouchebti and her colleagues.

But when they gave hornets nothing to eat for a week except sugary solutions containing different quantities of ethanol – between 1 and 80 per cent – the hornets' behaviour and lifespan remained unchanged. The 80 per cent solutions contain four times as much alcohol as anything found in nature (*PNAS*, doi.org/nn9q).

VLADIMIR_KAZACHKOV/SHUTTERSTOCK

The oriental hornet (*Vespa orientalis*) could drink you under the table

Analysis of the genomes of several hornet species suggests the insects have two to four copies of a gene that produces NADP+, a compound that helps break down alcohol. The researchers think this might help explain why the oriental hornet – and possibly others – can handle their booze so well.

The hornets' penchant for alcohol might give them a competitive edge when it comes to eating fermented foods, says Irene Stefanini at the University of Turin in Italy. She says their tolerance may be related to the fermenting brewer's yeast *Saccharomyces cerevisiae*, which her studies have shown reside within hornets' intestines. ▮

Sofia Quaglia

Mathematics

Amateur sleuth finds largest-known prime number

Matthew Sparkes

AFTER a six-year drought, we now have a new largest-known prime number, thanks to an amateur mathematics enthusiast.

Prime numbers are those divisible only by 1 and themselves, such as 2, 3 and 5. There are an infinite number of primes, but proving which numbers are prime becomes harder the larger they get. We can now add $2^{136,279,841} - 1$ to the list, which at 41,024,320 decimal digits long is the biggest prime number known.

It was discovered by a relatively new member of a group called the Great Internet Mersenne Prime Search (GIMPS), where thousands of people have downloaded software to hunt for prime numbers. Those who find one earn a place in prime number history and a $3000 prize. This is the first prize to be awarded since 2018.

The new prime number, labelled M136279841 by the GIMPS group, was found by Luke Durant, who formerly worked for Nvidia as an engineer developing graphics processing units (GPUs). He has been searching for big primes for just under a year.

All previous GIMPS discoveries were made by computer CPUs in relatively humble personal computers, but Durant used a GPU system for its number-crunching abilities. He networked thousands of GPUs housed in 24 data centres across 17 countries. "It was a pretty big surprise, but I had been working hard to grow the system," he says.

The new prime is the 52nd of a type called Mersenne primes to be found. These are exactly one less than a power of two, making them slightly easier to find.

"There's no use for extremely large prime numbers now, but it's not at all inconceivable that one day somebody will find something," says Kevin Buzzard at Imperial College London. ▮

Neuroscience

Woman's brain shrinks while taking birth control pills

Grace Wade

THE largest brain imaging study of a woman to date shows that hormonal birth control can decrease brain volume, but it isn't clear what effect, if any, this has on brain function.

Hormonal contraceptives have been around since the 1960s. Yet scientists only began investigating their potential effects on the brain in the past decade or two, says Carina Heller at the University of Minnesota, whose brain was scanned in the new study.

Studies have shown differences in brain volume between women who take hormonal contraceptives and those who don't. But no one had studied a brain before, during and after hormonal birth control is taken.

Heller, who was 30 years old when the study began, had previously used hormonal birth control for 12 years but had stopped taking it about five years before the study.

Heller's colleagues scanned her brain using magnetic resonance imaging (MRI) five times a week, at the same time each day, for five weeks while she wasn't using birth control. She then started taking birth control pills that contained synthetic forms of oestrogen and progesterone – one of the most popular forms of contraception in many countries, including the US and the UK.

75
brain scans showed how a brain changed over time

Three months later, Heller had 25 more scans across five weeks. She then stopped using the oral contraceptive and, three months later, repeated the scanning procedure for a final five weeks, making 75 brain scans in total.

As part of the study, Heller measured her body temperature and provided a blood sample before each scan to determine what phase of her menstrual cycle she was in. She also completed daily questionnaires to track her mood and anxiety levels and logged her sleep, and water, alcohol and caffeine intake each day. Heller tried to keep her physical activity and diet consistent throughout the study.

The result was a detailed picture of how her brain changed across both her natural menstrual cycle and with hormonal contraception. She presented the findings on 7 October at a Society for Neuroscience meeting in Chicago.

The volume of Heller's cerebral cortex – the brain's outermost layer – was 1 per cent lower while she was on birth control compared with when she stopped the medication. This is in line with previous studies that have indicated hormonal birth control may decrease volume in certain areas of the cortex.

Heller says a decrease in cortical volume isn't necessarily a bad thing. For instance, it also occurs during puberty and pregnancy when the brain refines neural pathways to make them more efficient. "This could be [happening] for the brain on oral contraceptives," says Heller. "But for now, we don't know what this means, and that's why it's so important that we do more research on the topic."

Hormonal birth control affects people differently, says Heller, so just because she experienced decreases in cortical volume doesn't mean everyone will.

Still, the work is a crucial step towards understanding why some people experience negative side effects, such as depression, on hormonal contraceptives while others don't, says Natalie Tronson at the University of Michigan. ▮

The effects of hormonal birth control on the brain are understudied

SHUTTERSTOCK/AREEYA_ANN

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Comment

If only they could talk

Communicating with animals may be closer than we think. But are we really ready for what they are going to say, asks **Chris Sherwood**

WHEN my ginger rescue cat Marmalade crawls on my lap and meows at me urgently, I often find myself wishing I really knew what was going on inside his head.

It might seem like storybook stuff, but communicating with animals may be closer than we think. Earlier this year, researchers revealed they had discovered that sperm whales in the east Caribbean use a phonetic alphabet of 143 combinations of clicks. They described it as the closest system to human language yet discovered and hope that one day they will be able to communicate with these complex, social creatures.

But it isn't just whales. Artificial intelligence is also being used to try to understand cats, bats and pigs. There's even a prize on offer to the team that first cracks two-way communication between humans and animals.

SIMONE ROTELLA

At the RSPCA, the UK's largest animal welfare charity, we recently launched our Animal Futures project, based on a futures report we commissioned into animal welfare. It explores five scenarios of what the world could look like for animals – and us – in 2050.

The most optimistic depicts a future where AI progresses so much that we can converse freely with the animals around us. This breakthrough triggers a step change in how we see and treat animals, sparking a debate on animal rights: should they be citizens with all the rights and responsibilities that come along with that status; should they be able to vote? In this scenario, we punish abuse of animals as severely as human crimes, use animal testimony in court and most of us go vegan overnight.

I would like to believe that this could happen. The RSPCA is celebrating its 200th year and it is undeniable that since our founders sat in a coffee shop in London in 1824, imagining a better world for animals, humans have revolutionised our treatment of them. They have better protections than ever before, we recognise their sentience in law and we have largely ended the casual cruelty for our entertainment – cockfighting in pubs or dog fighting in the streets in the UK, for example – that our founders campaigned against.

At the same time, however, it is also undeniable that we have become disconnected from animals and turned them into commodities. If we have imagined communicating with them, we probably picture chatting away to our cats and dogs at home.

But what about the animals that end up on our plate or in laboratories? The chicken that grows so fast that, by the time she is just over a month old, she struggles to stand. The hen that lives her life in a cage the size of a piece of paper or one of the nearly 150,000 rats – those intelligent creatures that can solve problems, giggle when tickled and form deep bonds with humans – that are used in experiments in the UK? Right now, it is easy to ignore because it is normalised and sanctioned by government and industry and takes place behind closed doors. AI could make it much harder to pretend we don't know.

Even our beloved pets might tell us things we don't want to hear – the ones we have bred with "cute" squished faces that struggle to breathe, or the ones we dress up or scare for clicks and likes on social media.

Animal behaviourists would tell us that we already communicate with animals, as we understand their body language. But, in reality, we turn a blind eye to what they tell us when it threatens the way we want to live our lives. Genuine communication with them through AI would make it harder to ignore how our everyday choices affect the animals around us.

I am not sure we are ready for what they have got to say, but we need to listen, because the futures of us all are intrinsically linked.

Chris Sherwood is chief executive of the RSPCA

This changes everything

Falling for my robotaxi

I have a confession to make. After taking a handful of autonomous taxi rides, I have gone from a hater to a friend of robot cars in just a few weeks, says **Annalee Newitz**

Annalee Newitz is a science journalist and author. Their latest book is *Stories Are Weapons: Psychological warfare and the American mind.* They are the co-host of the Hugo-winning podcast *Our Opinions Are Correct*. You can follow them @annaleen and their website is techsploitation.com

Annalee's week

What I'm reading
Neuroscientist Kelly Clancy's Playing with Reality, *a history of gamification and game theory.*

What I'm watching
Slow Horses, *a masterclass in the "sleazy, disgusting genius" subgenre.*

What I'm working on
Research for a big project about the ancient history of parties and celebrations.

This column appears monthly. Up next week: Rowan Hooper

I TOOK my first ride in a Waymo robotaxi last month, and now I'm obsessed. I have taken five autonomous car rides since, and even convinced two reluctant friends to do it too. Here's how I went from a hater to a cautious friend of robot cars in five weeks.

Waymo's parent company Alphabet – which also owns Google – recently launched a pilot programme in San Francisco. When I was ready to hail one, I simply downloaded an app that closely resembles a rideshare app and pushed the call button. Within minutes, a white Jaguar SUV rolled up in front of my house, with its large top hat of whirling lidar sensors and cameras. A light on the roof flashed my initials.

When I pushed the "unlock" button in my app, the passenger doors extruded handles and I jumped into the front seat next to... an invisible person. Truly, that is how it feels to ride shotgun in a Waymo, as the steering wheel spins on its own. It reminded me of being 7 years old on Disneyland's Haunted Mansion ride, where a holographic ghost appears in the carriage beside you.

My point is, yes, it did feel a little scary to be sitting by myself in a car that was driving on its own. A female voice came over the speakers reminding me to buckle up, then asked me to be patient if we went a little slowly because "I'm a polite driver".

Screens in the dashboard and back of the car showed what the car "saw" as it drove. It reminded me of the interface of *Pokemon Go* – a blocky, smoothed-out version of the real streets and buildings around you. Cars appeared as rectangles and humans were stick figures walking in little puddles of light. My robotaxi's path was a bright line, weaving around these obstacles, paying attention to the stop signs and street lights that also popped up on the screen.

Seeing through the car's eyes helped me get over my initial nervousness. I was more aware of my environment than I have ever been as a driver. Plus, there was a button to call for assistance from Waymo, as well as a "pull over now" button, which I found very comforting.

Overall, during my six rides, the car's performance in odd situations has been good. It avoided a cyclist who shot into an intersection out of nowhere, and somehow navigated between two huge trucks on a narrow street.

> **"There is something comforting about being driven around by a machine that is friendly and never tired or cranky"**

Sure, it made weird decisions at times. At one point, my car took a narrow, winding side street full of traffic and pedestrians instead of going on a wide, fast thoroughfare. Other reported issues include cars stopping for too long at crowded intersections, randomly honking in parking lots and, in one case, hitting a telephone pole.

There are also problems you might not expect. One night when I called a Waymo, the car rolled up with a large phallus doodled across its doors. Oops – it is easy to graffiti a car that nobody is driving.

Then there is the issue of people taking advantage of a safety feature that prevents the car from moving forwards if someone stands in front of it. Recently in San Francisco, two men stepped into the street to block a woman's Waymo, refusing to move unless she gave them her phone number. Ultimately, the men wandered off and she was left frightened but physically unharmed, yet her experience raises questions. What if thieves stood in front of a Waymo while their buddies smashed the windows and demanded passengers' stuff? Riding in a Waymo is safer in many ways, but it can also turn passengers into sitting ducks.

There are labour issues, too. Rideshare companies like Uber cut into the livelihoods of taxi drivers, undermining unions and creating a class of gig workers with few rights and no benefits. Robotaxis promise to eliminate rideshare and taxi driver jobs. Plus, the tech underlying autonomous cars is already being used in trucks and buses. So each time I ride in a Waymo, I know the ghost at the steering wheel is the ghost of a dead job.

Still, it is impossible for me to ride in a robotaxi and not develop warm feelings towards it. There is something comforting about being driven around by a machine that is friendly, never tired or cranky and doesn't infodump at you about conspiracy theories.

But there is more going on here. As Cynthia Breazeal, a robotics researcher at the Massachusetts Institute of Technology, found in 2001, humans will anthropomorphise anything – even a simple robot – if it behaves in a way we recognise as emotional.

That was definitely the case for me when the car told me it was "polite". I couldn't stop myself from saying "thank you" out loud. I felt cared for. And when it expertly zig-zagged around road works, I exclaimed "good job!" as if it were my cat. I don't know where my relationship with these robotaxis is going – it's complicated – but I think we might have a future together. ▮

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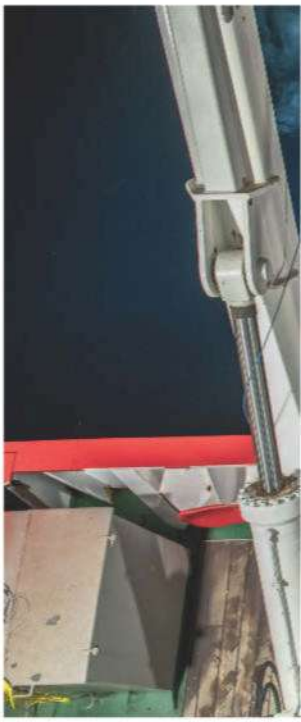

CLOCKWISE FROM TOP L: JAMES BLAKE/FALKLANDS MARITIME HERITAGE TRUST; ESTHER HORVATH; FALKLANDS MARITIME HERITAGE TRUST

New Scientist video
Finding Ernest Shackleton's sunken ship
youtube.com/newscientist

Shackleton saga

National Geographic
5 November

SLOWLY cracking through the dense pack ice of Antarctica's Weddell Sea is hefty, ice-breaking research vessel S. A. Agulhas II (far left, top). It was part of Endurance22, a successful 2022 expedition to locate the sunken ship of explorer Ernest Shackleton.

Endurance went down in 1915 after it was trapped by pack ice during its first voyage – leaving him and his crew of 27 men stranded, with little hope of rescue. "The story of survival of Shackleton and the crew of the Endurance is a legendary feat of leadership, grit, determination and perseverance against all the odds," says Nico Vincent, deputy leader of the Endurance22 expedition. In new book *Endurance*, he and the wreck mission leader John Shears detail the search for the lost ship.

A stunning bird's-eye view (near left, top) shows members of Endurance22's subsea team edging a returning underwater autonomous vehicle into position at the vessel's stern before heaving it onboard again.

But, fittingly, centre stage (bottom) is taken by an amazing mosaic of over 25,000 images of the wreck itself. It reveals an incredibly well-preserved ship, its masts, anchors and steam engine funnel all still present, while the hull is also intact, resting upright on the seabed. Shears and Vincent hope the story of the ship will offer a fresh perspective on the epic tale for a new generation.

Chen Ly

Endurance: The discovery of Shackleton's legendary ship by John Shears and Nico Vincent is published on 5 November

For a review of Arctic horror drama *The Terror*, see page 30

Editor's pick

Your views on how to reboot democracy

5 October, p 32

From Roger Morgan, Presteigne, Powys, UK

Laura Spinney's article proposes the use of randomly selected citizens' assemblies to harness the creativity of the crowd to generate good solutions to public problems. The idea is a return to Athenian democratic principles, using new decision-making processes and new technology to shift governing decision-making closer to the general public than it is in current, rather distrusted systems.

But citizens' assemblies haven't been convincingly representative so far. Random invitations to the public to participate ("sortition") have usually led to only a single-figure percentage accepting, reducing the initial value of random selection. Moreover, the representativeness of assemblies as "mini-publics" has relied on selection by criteria such as gender, age and initial views on subjects to be considered. But there is little evidence about what criteria truly maximise representativeness.

We need to properly test the validity and reliability of potential new democratic processes.

From Ian McKinley, Ennetbaden, Switzerland

There is no doubt that implementing the ideal of citizen participation is very challenging, but it is a shame that the country with probably the most effective system of direct democracy wasn't examined: Switzerland. The requirements for such democracy to work as mentioned in the article can all be seen in Swiss culture and its educational system. That this brings benefits should be clear from the fact that this small country has one of the highest standards of living in the world.

From William Hughes-Games, Waipara, New Zealand

There is no need for digital technology to create true democracy for the people, by the people. Money corrupts politics. Make it illegal for vested interests to give money or anything that costs money to politicians before, during or after a term in office and watch those whose only interest is to enrich themselves run for the hills. A responsible, public-spirited group will take their place and politics will repair itself.

From Terry Klumpp, Melbourne, Australia

I favour the idea of a lottocracy because it would, in effect, eliminate those career-politicians who have rarely or never had a real job outside politics and so haven't experienced what it is like to actually have to work for a living. Some may also be subservient to their rich donors. Because of this, we end up with an "oligarchy" under the guise of a democracy.

Do we make reality? Maybe, maybe not

12 October, p 40

From Adrian Smith, Addingham, West Yorkshire, UK

I don't buy the idea that "we make reality". I believe subatomic entities exist independently of us and that these entities oscillate and interact with wave-like properties. However, the equations we use to describe these interactions are human-made, so it is at this point that we create our own reality.

From Larry Stoter, The Narth, Monmouthshire, UK

The idea that there is no objective reality puts the "observer" centre stage. But what constitutes an observer? Much of quantum physics avoids this issue, implying that only humans qualify. Surely it is arrogant to think that only we can be observers?

If the history of science teaches us anything, it is that making humanity in any way central to an idea sooner or later proves to be wrong. When does an entity stop being an observer – a cat can clearly be one, but can a bacterium, a grain of sand, a proton? Daniele Oriti's ideas come close to panpsychism, which posits that consciousness in some degree is fundamental to entities.

From Patrick Butterly, Buckfastleigh, Devon, UK

Oriti, a theoretical physicist, says that "we have to embrace the fact that we make reality". That might come as a shock to scientists, but not to poets and novelists: they have always thought it obvious that reality inheres not in the common phenomenal world, but in the perceptions of that world in individual minds.

From Faith Anstey, Dalguise, Perth and Kinross, UK

If we make reality, are we part of reality or not? If we are, do we make ourselves – and all our thoughts, theories and so on? And if not, why not?

My frenemies seem to be following me

19 October, p 40

From Maggie Cobbett, Ripon, North Yorkshire, UK

David Robson's piece on "frenemies" set up an intriguing question in my mind. Why is it that people I would really like to see again rarely cross my path, whereas those I would prefer to avoid appear everywhere I go? Some kind of negative attraction at play, perhaps?

Here's to revelling in the mystery of the cosmos

12 October, p 44

From James Hardy, Belfast, UK

Leah Crane's article about seeing Saturn through a telescope as a child and being inspired to love space was fascinating. It called to mind philosopher Bertrand Russell, who, although an atheist, freely admitted to the immense mystery of the cosmos: "We know very little, and yet it is astonishing that we know so much, and still more astonishing that so little knowledge can give us so much power."

No shock that pyramids were an ancient favourite

19 October, p 37

From Robert Masta , Ann Arbor, Michigan, US

Many thanks for the Flint Dibble interview. It is no great surprise that multiple cultures would independently develop pyramids. We humans have a natural affinity for high places, probably dating back to spotting predators or enemies as well as a desire to be closer to the sky.

A pyramid is a simple structure that can be built without the fancy lifting technology required for a tower, and can be made intrinsically stable. An ancient project engineer could demonstrate project feasibility to the ruling elite using a model comprehensible to any child.

Water from air: the Incas got there first

19 October, p 10

From Alex McDowell, London, UK

The idea of extracting drinking water from the air, as deployed in a Florida children's hospital after recent hurricane disruption, isn't new. The Incas, living in mountainous regions too high to get rain, channelled dew into cisterns and may have used fog fences to collect moisture that was hanging in the atmosphere.

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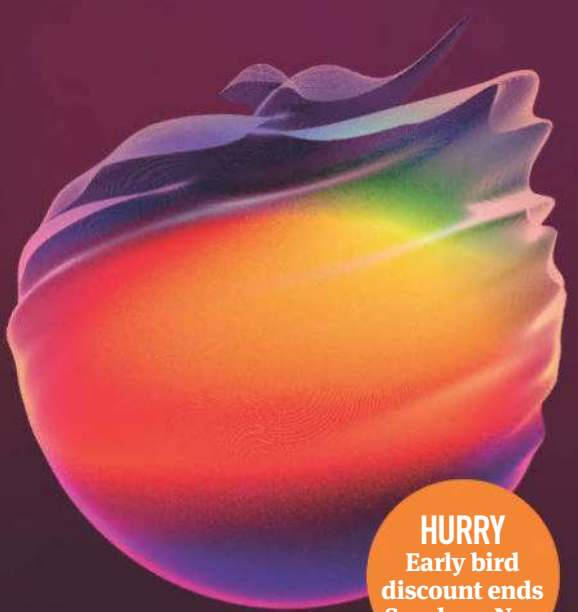

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Cashing in on killer whales

A tense and thriller-like documentary digs deep into the murkiest waters surrounding the cruel trade in orcas, finds **Katie Smith-Wong**

Film

Orca – Black & White Gold

Sarah Nörenberg

Terra Mater Factual Studios

Distribution pending

WHEN it comes to orcas, also known as killer whales, films such as the documentary *Blackfish* and family adventure *Free Willy* have shown the distressing effects captivity can have on their behaviour, especially towards humans. Real-life cases include Tilikum, who was involved in the deaths of two trainers, one at Sealand of the Pacific, in British Columbia, Canada, the other at SeaWorld in Orlando, Florida, and a trespasser at the latter site.

A new docu-thriller by director Sarah Nörenberg highlights another, darker side of captive whales – their commercialisation.

Orca – Black & White Gold focuses on the efforts to liberate a pod of orcas and beluga whales from a site in Srednyaya Bay, near Nakhodka, in the far east of Russia, which were being held as part of efforts to populate oceanariums in China. The film highlights the ongoing issue of marine mammals being captured for commercial purposes.

It starts with a scene straight out of an action movie as a group of hunters looking to capture orcas target a pod in a high-speed chase on the open water. As they throw nets around the mammals, one crew member shrugs his shoulders at the number of the orcas being captured. With orca cries echoing in the background, it sets a dark and discomforting tone for the documentary.

The Srednyaya site was dubbed a "whale jail" by the press after reports about it appeared in the independent Russian newspaper *Novaya Gazeta* in 2018. As a result, releasing the captive mammals became both a priority and a sociopolitical mission.

Nörenberg concentrates her documentary mostly on the activities around Srednyaya Bay, and on the lucrative sale of orcas from Russia to China for its new aquariums and attractions.

The film follows various people as they track the welfare of captive orcas. From the outset, it exposes the lack of compassion of hunters and the authorities towards the whales. We see the incredulity and horror of a group of marine experts as they watch a film of professional hunters fail to save an adult orca trapped in a net. And one Russian hunter says he would rather move to the Antarctic than stop whale hunting but has mixed feelings about keeping the animals in captivity.

> **"The film doesn't shy away from the politics of the orcas' sale, and the secrecy of the Srednyaya Bay rescue"**

With so many parties with such different opinions, Nörenberg maintains the documentary's emotional balance about captive orcas by repeating facts rather than lapsing into bias.

She also holds onto the film's serious tone, reminding audiences that commercial whale capture is not to be taken lightly. Several compelling moments change the pace by using animation to drive home facts and figures about the industry, from the first orca sale in the 1960s to SeaWorld's stock crash following the release of *Blackfish* 50 years later.

A killer whale can fetch millions of dollars, making them an expensive commodity. And with Russian president Vladimir Putin a constant background presence, the documentary doesn't shy away from the politics driving the sale of orcas, and the secrecy of the Srednyaya Bay rescue.

For instance, we see that a press conference in Moscow about the rescue mission builds suspicion about its lack of transparency, as well as the legality of whale capture and the culpability of those who engage in the practice. Kirill Viktorovich Kolonchin, director of the Russian Research Institute of Fisheries and Oceanography (VNIRO), is shown unable to answer questions about the orcas' future – fuelling worries about whether the rescue will take place at all, and feeding into the "thriller" tone set by the documentary's opening scene.

Compelling and insightful, *Orca – Black & White Gold* is an enlightening look at the murkier side of commercial whale capture and it raises awareness about the treatment of these animals in captivity. ▮

Orcas in the Sea of Okhotsk, off Russia's Kamchatka peninsula

TERRA MATER STUDIOS GMBH

Katie Smith-Wong is a film critic based in London

The real asteroid plan

Forget giant space rocks, smaller ones that could wipe out a city are what we really need to fear, discovers **Chris Stokel-Walker**

Book

How to Kill an Asteroid
Robin George Andrews
W.W.Norton

JAMES THEW/ALAMY

A meteor burns up as it nears Earth, unlike asteroids that can hit the surface and wreak havoc

FOR a generation of scientists – and science fiction fans – Hollywood movies like *Armageddon* and *Deep Impact* have helped shape and scare society. The risk of an asteroid wreaking havoc on our planet, wiping out large swathes of Earth and the humans on it, are real.

But as science journalist Robin George Andrews writes in *How to Kill an Asteroid: The real science of planetary defence*, the danger isn't from super-large space rocks that could be on a collision course with us, but from the smaller ones.

We have spotted those larger bodies that could careen into our world and know we are safe from them for now, says Andrews, but the slightly smaller ones that slip through our monitoring systems could cause nearly as much havoc. Some 25,000 asteroids, each large enough to destroy a city, are on orbits that could threaten Earth, but we don't yet know where they are.

This vividly written book, which reads as much like a thriller as the film plots it is trying to correct, helps explain the risks involved. From the first page, Andrews throws us into the action, with his own science-fictionalised look at an imagined asteroid collision with Seattle in 2046, which could create a hole about 1220 metres wide and nearly 500 metres deep at the point of impact. The language is beautifully chosen, and the future leaps into life through his words.

Books like this usually take one of two tacks. They can oversimplify, leaving slightly more scientifically experienced readers feeling unfulfilled as generalisation takes precedence over fact and detail is blurred in favour of readability. Or they can force readers into submission through scientifically accurate, but deathly prose.

Walking this tightrope is tricky. Well-sourced and rigorous analysis often doesn't make for engaging writing. And if you commit the cardinal sin of judging this book by its cover – a schlocky sci-fi design, giving the impression of a young adult novel or 1970s B-movie – you might worry about the opposite. Neither are a concern here.

Andrews's dexterity in explaining complicated concepts, including how to knock asteroids off-orbit, makes this book well worth picking up, but that verbal vivacity is matched by deep reporting.

He isn't in the press room where the world's media are cooped up at the September 2022 culmination of humanity's wild, multi-year plan to deliberately crash a spaceship into an asteroid and change its trajectory, a NASA mission called DART (Double Asteroid Redirection Test). Instead, thanks to an entrepreneurial decision to shake off his media minders, he is at a barbecue held on the same campus, getting the real low-down among the staff who worked on the mission as they see it successfully pulled off.

The innate drama of defending against killer asteroids goes a long way towards explaining its appeal for Hollywood. But the detail of what it takes to compute the variables that go into launching a mission to disrupt an asteroid on course for us could easily turn a pacey yarn into a treacly mess.

Luckily Andrews never gets bogged down in the science, but also doesn't leave out any important information. You will finish the book as informed as you are entertained.

You may also end it feeling a little worried. Talk of potential disasters is prone to invoke apprehension, of course – and one chapter, where Andrews sits in on an exercise that war-games the international response to an imminent asteroid hit that results in the entire destruction of Winston-Salem, North Carolina, is hauntingly written. But there is positivity too, as we realise the brightest minds are working to protect us from doomsday. ▮

Chris Stokel-Walker is a writer based in Newcastle upon Tyne, UK

New Scientist *recommends*

Timothy Revell
Executive Editor
London

The new BBC series **Ludwig** seems like a classic murder mystery. Each episode of the six-parter starts with an untimely, odd death and ends with a here's-how-it-happened moment from a genius sleuth. Yet somehow, it feels fresh, surprising and funny.

The story follows John Taylor (David Mitchell, pictured), a recluse and legendary puzzle setter, known by his pseudonym "Ludwig". When his identical twin brother James (also Mitchell) disappears, his sister-in-law begs John to help. So he impersonates his brother (a detective chief inspector) to find out what happened. No one at the station notices

DAVID EMERY/BBC/BIG TALK STUDIOS

the swap and John finds himself cracking cases as if they were puzzles at the back of a magazine.

I also enjoyed reading **When We Cease to Understand the World** by Benjamín Labatut. I knew little about it before starting and recommend that you take the same approach. It's an unusual book about mathematics and the mind; part-truth, part-fiction. I will say no more!

The TV column

Voyage to hell

Fresh discoveries about the 1845 Franklin expedition to find the Arctic's Northwest Passage make it worth revisiting an excellent horror drama. It is beautifully crafted and a worthy tribute to the lost sailors, says **Bethan Ackerley**

Bethan Ackerley is a subeditor at *New Scientist*. She loves sci-fi, sitcoms and anything spooky. Follow her on X @inkerley

ITVX

James Fitzjames (Tobias Menzies, left) and John Franklin (Ciarán Hinds)

IN SEPTEMBER, an awful truth was brought to light.

Ever since contact was lost with the Franklin expedition, an 1845 attempt by the British Royal Navy to find a path through the Arctic's Northwest Passage, historians and scientists have tried to find out what went wrong. Investigations discovered hints of the horrors the sailors may have faced, including pack ice, hypothermia, lead poisoning and starvation. Eventually, the wrecks of HMS Erebus and HMS Terror, the mission's twin ships, were located.

But another, more personal challenge endures, that of accurately identifying the remains of many of the 129 souls lost. New research by Douglas Stenton at the University of Waterloo in Canada and his colleagues has done just that for James Fitzjames, a senior officer on HMS Erebus. Most significantly, it is the first time it has been possible to identify an expedition member whose body was cannibalised.

It is a sorry tale, and I wouldn't blame you if you shied away from learning more about the expedition. But if, like me, you have a lingering fascination with the fate of these men, watch the first season of AMC's horror anthology series *The Terror*, from 2018, which is based on the ill-fated mission – and adds a supernatural twist. It isn't a literal retelling of the tragedy, but it is a beautifully crafted show, and a fitting tribute to the sailors.

> **"We have been trying to piece together what happened for years. The show is part of that continuing history"**

At the heart of *The Terror*'s version are three officers. One is Fitzjames (Tobias Menzies), here characterised as the dashing, somewhat arrogant favourite of John Franklin (Ciarán Hinds), the amiable but glory-hunting leader of the expedition. The crew of HMS Terror are led by Francis Crozier (Jared Harris), Franklin's melancholic second-in-command, who is among the vanishingly few polar veterans on either ship.

All three are limited, flawed and buckling under the social stigma of those times: of being illegitimate, a failure or Irish, respectively. The world that broke and bent these men into shape has sent them to carve a path through the ice, straight into a sea of troubles.

Among these is the Tuunbaq, a polar bear-like creature inspired by Inuit myths. A lesser show would have turned this into a symbol of evil, but in *The Terror*, it is simply a manifestation of nature's indifference, its "savagery" just one of the abominations ahead, not least the men themselves. Their distrust of the Inuit communities also dooms them as much as their encounters with the Tuunbaq, horrifying as those are.

We know from an epigraph to the series that all the sailors are destined to be lost. Remarkably, *The Terror* makes you forget that: each death and indignity is as keenly felt as if the men's fates were uncertain. That is the result not only of excellent writing and an exemplary cast, but the loving way the series includes ephemera the expedition left behind, clues that would later prove vital.

We have been trying to piece together what happened to the Franklin expedition for years. The first season of *The Terror* may be a drama, but it is also an important part of that continuing history because it speaks vividly to our fascination with the men who died, not simply the particulars of their doom. I struggled against feelings of dread to watch it again for this review, but once I began, I felt compelled onwards to its harrowing conclusion.

I am confident you will, too.

TV

The Terror
AMC
Showrunners: David Kajganich, Soo Hugh

Bethan also recommends...

TV

Fortitude
Creator: Simon Donald
Sky Atlantic
Set in the sleepy (fictional) town of Fortitude in the Norwegian Arctic, this horror series hinges on a thawing glacier and some truly terrifying polar bears.

Book

Polar Horrors: Strange tales from the world's ends
Editor: John Miller
Courtesy of the British Library, this collection of classic horror short stories is a perfect accompaniment to The Terror.

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THE SMART GUIDE TO NUTRITION

SPEND any time online and it seems like everyone has a different view about what and how we should be eating – even the experts. So, over the next eight pages we delve into some of the hottest nutrition trends of the moment – from diets that supposedly balance our hormones or reduce inflammation to personalised nutrition and fermented foods – to find out whether they stand up to scrutiny.

Among other things, we weigh up whether the timing of our meals is more important than what we eat, investigate whether snacking is really as bad as it is cracked up to be and discover the one thing you should be obsessed with eating more of (but probably aren't).

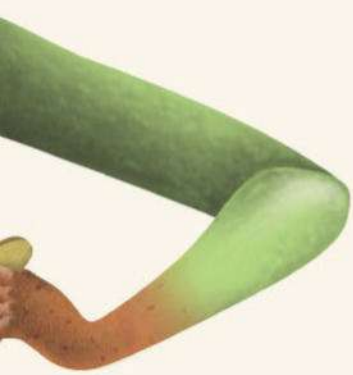
So read on to find out what should really be on your plate if you want to boost your chances of a longer and healthier life.

COULD *WHEN* YOU EAT MATTER AS MUCH AS *WHAT* YOU EAT?

It is close to midnight and I am bingeing both on a Netflix show and leftovers from the fridge. I know I will regret it in the morning – and perhaps for years to come.

With my late-night feasting, I am inadvertently playing fast and loose with a system that evolved to keep my body in sync with the natural 24-hour cycle of day and night. Its effects include setting optimum times to eat, and there is emerging evidence that overriding this schedule can have severe consequences for health.

The syncing begins in a small cluster of neurons in the brain called the suprachiasmatic nucleus (SCN), which is the body's central timekeeper. Its function is to make sure biological processes such as falling asleep occur at the optimal time. The SCN is reset daily by light and darkness, creating a roughly 24-hour cycle called the circadian rhythm. It also coordinates appetite to ensure that we have adequate supplies of energy during the day and can get through a night's sleep without being awoken by digestion or hunger. This translates into natural peaks in appetite in the morning and early evening. Processes involved in the digestion, absorption and metabolism of food are similarly coordinated by the SCN to be primed for action at the appropriate times.



BRETT RYDER

But the SCN doesn't solely call the shots. The body also has numerous secondary clocks in peripheral tissues and organs that largely take their orders from the central clock, but also respond to external cues called zeitgebers (German for "time givers"). The most important of these is feeding, which causes the release of hormones involved in metabolism and satiety. Zeitgebers also reset the peripheral clocks in the gut, liver, pancreas, heart and adipose tissue.

Ideally, the central and peripheral clocks are in sync. But eating at the wrong time can create a mismatch. That spells trouble for our waistlines and general health. Feasting when the SCN wants us to fast has been linked with obesity, type 2 diabetes, high blood pressure, raised cholesterol and cardiovascular disease. Part of the problem may simply be that eating out of hours means we consume too many calories, according to Olga Pivovarova-Ramich at the German Institute of Human Nutrition Potsdam-Rehbrücke. But timing also appears to be a crucial factor: a 2017 analysis of night-shift workers found that they were more likely than day-shift staff to become overweight or obese even when consuming the same number of calories.

> "Overriding the body's natural 24-hour cycle can have severe health consequences"

Despite this clear association between meal timing and health, "the underlying mechanisms remain largely unknown", according to Pivovarova-Ramich. We know that thermogenesis – the generation of body heat through metabolism – is under circadian control and is higher in the morning. This is also true of our resting metabolic rate, the amount of energy our bodies use in the absence of exercise. It could be that, because of these factors, calories consumed in the "biological night" are shunted into fat storage rather than burned.

In today's world, there are endless opportunities to grab a tasty zeitgeber at the wrong time. Many of us live in 24-hour societies where food is widely available at all hours. Artificial light, such as from TV screens, may also play a role. It can throw the SCN out of whack, adding another source of confusion between the central and peripheral clocks. Artificial light can also extend the active portion of the day and shrink the biological night, which studies in mice suggest may lead to increased overall food intake and weight gain.

So, when is the right and wrong time to eat? It depends to some extent on individual biology. Everyone has a "chronotype", which is their largely innate preference for when their waking hours start and end. Around 20 per cent of us are "owls", who naturally wake late, go to bed late and function better in the afternoon. Another 20 per cent are "larks", who wake and sleep early. The rest lie somewhere in the middle. These different chronotypes are largely a result of genetic differences that affect circadian rhythms. But as a general rule of thumb, it is wise to get most ›

of your calories earlier in the day and avoid eating altogether during your biological night, which for non-owls starts around 8pm. Studies have shown that night eaters, who consume the majority of their calories after this time, tend to have a higher body mass index.

One way to avoid eating too late is through time-restricted eating (TRE), a popular form of fasting where all the day's calories are consumed within a limited and consistent window, typically 8 to 10 hours. In practice, that means either fasting throughout the morning or stopping eating in the late afternoon, which are known as late and early TRE respectively. Many studies show that both versions have metabolic benefits ranging from better blood sugar control to healthier cholesterol levels.

Exactly why isn't clear. "Unfortunately, there's not been much mechanistic work on time-restricted eating in humans," says Courtney Peterson at the University of Alabama at Birmingham. But circadian rhythms appear to be involved. TRE has been shown to extend lifespan in animals, though some research has cast doubt on the practice, with links to increased risk of death from heart disease. What's more, we haven't followed people on these diets for long enough to know if TRE has longevity effects in humans, but people practising it consistently lose a bit of weight, says Peterson. There are also positive effects on blood sugar control and blood pressure, she says. Tellingly, though, these are only seen with early TRE, perhaps because it aligns better with circadian rhythms. Another good reason to ditch the midnight feasts.

Graham Lawton

WHAT'S THE TRUTH ABOUT HORMONE-BALANCING DIETS?

Spend more than 5 minutes on Instagram or TikTok – especially as a woman of a certain age – and you are likely to meet a fit, attractive person showing you what they ate today. It is usually a bowl of oats, flaxseeds and berries, or a plate of leafy greens with lean meats or other "quality proteins", or a salad of raw carrots and little else, all enviably presented and accompanied by the claim that these foods balance excess oestrogen, lower the stress hormone cortisol, support adrenal function or even help you get rid of that "hormonal belly".

So-called hormone-balancing diets aren't exactly new: self-help books positing hormonal balance as the way to wellness began appearing in the early 2000s, marrying scientific-sounding claims with weight-loss plans. But what does "hormone imbalance" really mean?

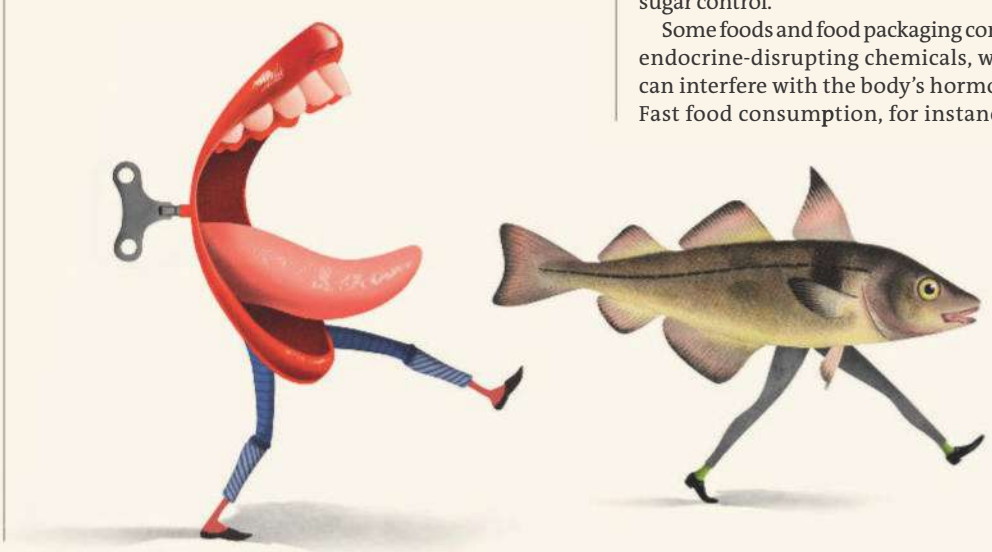
Not a lot, as it turns out. Hormones are the chemical messengers produced by endocrine glands located throughout the body, such as the thyroid, pituitary gland, ovaries and testes, that orchestrate many essential functions. "Hormones basically run the show, so to speak, in our bodies," says Amelia Sherry, a registered dietician in New York. "Different hormones regulate everything, including sleep, hunger and fullness, growth, sexual development and desire, pregnancy, energy metabolism, blood sugar and more."

So the concept of "balance" makes little sense in the perpetually changing endocrine system. "'Hormonal imbalance' is not a term endocrinologists... readily use because it suggests that something is wrong if hormones, when measured, are not always in the 'normal range'," says Deena Adimoolam at the Endocrine Society. "The truth is, our hormones fluctuate all day and all night."

For the most part, this system runs itself. And when it doesn't, it is often because of something more serious than carrot salads can cure. Some conditions can induce problematic levels of a specific hormone in the body, whether that is too little or too much. Polycystic ovarian syndrome (PCOS), one of the most common conditions addressed by influencers, is characterised by an excess of androgens, for example, while hypothyroidism occurs when the thyroid produces too little thyroxine and triiodothyronine. In other cases, too much or too little of a hormone can indicate a tumour in a gland.

It is true, however, that our diet does play a part . "What we eat or don't eat can impact our hormonal production," says Sherry. The effect can be both direct, causing our bodies to make more or less of a specific hormone, or indirect, by changing cellular sensitivity to hormonal signalling. These effects are most obvious with the hormones regulating blood sugar and satiety, where certain foods can exacerbate existing issues, says Adimoolam. "If you have type 2 diabetes, eating too much glucose – sugar – can lead to a further increase in the hormone insulin, leading to more insulin resistance, which can lead to worsening blood sugar control."

Some foods and food packaging contain endocrine-disrupting chemicals, which can interfere with the body's hormones. Fast food consumption, for instance, is



linked to higher levels of chemicals used in plastics called phthalates, probably due to either the packaging or the processing procedures. Even relatively little exposure to such chemicals can have significant biological and developmental effects in both humans and wildlife.

The interaction between hormones and environment isn't as simple as many influencers imply, however. "There are many complex factors that go into hormone production, hormone signalling and how hormones play with one another," says Sherry. So, although a careful diet can help reduce ingestion of environmental endocrine disruptors, it cannot cure conditions like PCOS. And there is no evidence that eating a diet rich in, for example, soy and flaxseeds – plant products full of phytoestrogens that mimic mammalian oestrogen – will "reset" your personal oestrogen levels, as is sometimes claimed.

Though many of the diets promoted as hormone-balancing aren't themselves dangerous, they may nonetheless have problematic effects. Some are designed to help with PCOS, perimenopause or menopause, and people experiencing these are at a higher risk of developing eating disorders. False information about what these diets can accomplish may only increase the likelihood of disordered eating among their target audiences, says Sherry. "These very real risks, coupled with the lack of reliable evidence that any one particular diet is going to cure or reverse hormonal changes related to PCOS or menopause, makes me very leery of any diet that claims as much," she says.

It may go without saying to view any nutritional advice delivered on TikTok with a degree of scepticism. But many of the hormone diets being touted on social media could be good for us – they just aren't rebalancing your endocrine system.

"The recommendations – to eat more wholegrains, more lean proteins, plant-based fats, fruits, vegetables and high-fibre foods – are the same dietary changes we recommend for disease prevention, longevity and overall health," says Sherry. "[But] will it cure your condition? No."

So, when it comes to hormone-balancing diets, don't believe the hype – although that doesn't mean they won't do you any good whatsoever.
Linda Rodriguez-McRobbie

IS SNACKING REALLY THAT BAD FOR YOU?

> "Research on the health effects of snacking has produced a dog's dinner of results"

We are often told not to eat between meals, and there is a general perception that snacking is unhealthy. But, as usual when it comes to food, temptation prevails.

Snacking is very common, and increasingly so. In the early 1970s, for example, US adults consumed about 18 per cent of their total calories in snack form. By 2010, that had risen to 23 per cent. Similar numbers have been recorded in the UK, Brazil and Norway.

Given how common snacking is, it would be nice to know whether the received wisdom is true. But research on the health effects of snacking has produced a dog's dinner of results. Some studies have found that, as expected, snacking has negative health consequences. But others have found the opposite.

To get a clearer picture, earlier this year, Sarah Berry at King's College London, who is also chief scientist at the Zoe nutrition app, and her colleagues, re-analysed data they had gathered as part of an experiment carried out in 2018 and 2019, in which around 850 participants recorded everything they ate and when they ate it across two to four days. They were also tested on a range of measures of cardiovascular health, such as levels of blood fats and glucose.

Berry and her team found that 95 per cent of people in the study snacked, which they defined as consuming food or drink at least 30 minutes before or after main meals. The average number of snacks per day was 2.28, and around 24 per cent of calories were consumed in snack form. The researchers also devised a measure of the nutritional quality of snacks, called the snack diet index.

Their overall finding was somewhat surprising: snacking, per se, isn't associated with negative health outcomes. This contradicts one of the most common arguments against snacking. "There are many people who say having multiple eating events throughout the day is bad for you," says Berry. "You need to give your body a rest."

Yet her team's results suggest this isn't the case. "There was no difference in health outcomes depending on the number of eating events," she says. "If you had three or if you had six, it didn't matter."

But snacking isn't a free lunch either. It depends on what you eat and when. Unsurprisingly, people who snaffled poor-quality snacks, such as biscuits, crisps and cakes, and/or ate after 9pm were worse off health-wise than those who didn't snack at all or who snacked on nuts, seeds, fresh fruit and vegetables.

"What seems to matter is the quality of the snack – obviously – and the timing," says Berry. The effect of late snacking may be due to the disruptions in circadian rhythms associated with eating at the wrong time (see "Could *when* you eat matter as much as *what* you eat?", page 33).

But here's the thing: people who snacked on healthy foods and didn't snack late were better off than non-snackers. Snacking on fruit, vegetables, nuts and seeds earlier in the day is associated with a healthier weight and body mass index.

That may be because well-timed, healthy snacks reduce hunger and overall calorie intake. In 2022, a team at Winona State University in Minnesota experimented with giving first-year college students – who often gain weight after starting university – a snack 90 minutes ›

before their evening buffet meal. They either got 190 calories of walnuts, a 190-calorie gummy candy or no snack. The snackers ate fewer calories' worth of food in the subsequent meal, and less overall, compared with the non-snack group, even with the snack factored in. The walnuts also proved more effective than the candy at reducing calorie intake. This suggests that eating a wholefood snack shortly before meals can reduce our overall energy intake.

Another thing to consider when reaching for a snack is why you are doing it. Research shows that most of us snack out of habit or boredom rather than hunger. "If you don't need the energy, that's where it becomes a problem," says Berry.

Richard Mattes at Purdue University in Indiana concurs with this view. He says our ability to gauge energy intake isn't precise, "so in the current environment where foods are abundantly available and social custom often dictates that we eat when we're not hungry, that tends to be the problem".

This means that the planning – or not – of snacks is important. "When snacking is a planned eating event, then compensation [for calories at mealtimes] seems to be stronger," says Mattes. "When it's an unplanned eating event, generally it's less well compensated and so the energy from those types of snacks tends to add more to total daily energy intake."

The take-home message is that snacking isn't automatically bad for your health – and can be positive. "If you are a grazer, as long as you're grazing on healthy food and not grazing late at night, current evidence would support that this can be part of a healthy, balanced dietary pattern," says Berry. "It's a simple dietary strategy that can improve your health."

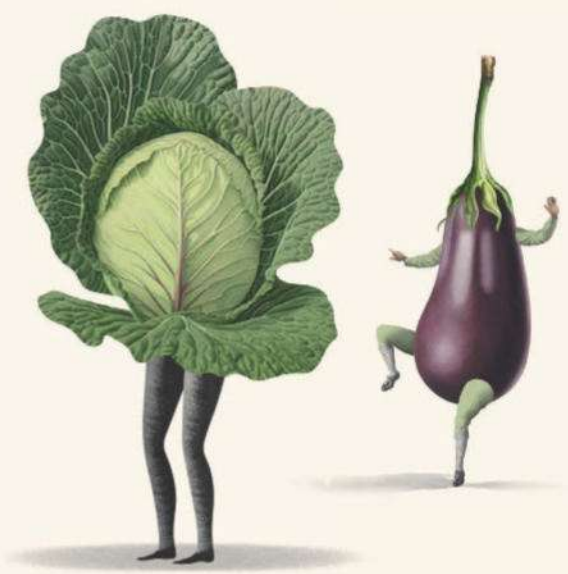
"I think we have to accept that people want to eat more times per day than they used to," says Mattes. "The real goal now is to understand how to incorporate it in a way that isn't problematic." GL

WHAT'S THE REAL SUPERNUTRIENT WE DON'T GET ENOUGH OF?

When it comes to our diet, there is an ever-changing list of things touted as the key to better health: cutting out carbs, eating like a caveman or dosing up on supposed superfoods such as turmeric. Most fail to live up to the hype – but there is one supernutrient that bucks this trend.

It is common knowledge that dietary fibre is good for you, but few of us appreciate just how far-reaching its health benefits go. Being in the know is worth your while, though, especially given that the diets common in high-income nations mean it is all too easy to miss out.

Many of us will have experienced first hand the effects of dietary fibre on our body. Sometimes dubbed "nature's laxative", a lack of it can cause constipation. But there is much more to fibre than bowel movements. Diets high in this constituent are associated with reduced risks of many health conditions, including cancers and heart disease. This is because fibre isn't just cardboardy filler, it is also food for the microorganisms in our gut. That means its effects can be felt throughout your body, as this microbiome influences the health of our immune system, brain and more, via the chemicals it produces.



"Fibre is the part of our diet that we cannot digest. Most comes from plant cell walls," says Petra Louis at the University of Aberdeen in the UK. Chemically, it is made up of long-chain carbohydrates. There are many types, the properties of which vary, including how soluble they are. They include resistant starch, found in unripened bananas and oatmeal, and cellulose, typically found in whole grains.

Dietary fibre was largely ignored until around 50 years ago. In 1969, surgeon Denis Burkitt began arguing that several bowel diseases, including colorectal cancer, were caused by a diet lacking in fibre. Decades later, findings supporting fibre's benefits have accumulated.

"The evidence for dietary fibre is now overwhelming," says Jim Mann at Otago University in Dunedin, New Zealand. He co-authored a 2019 meta-analysis covering 185 studies that tracked 58 clinical trials. This found that people who ate the most fibre had a 15 to 30 per cent lower risk of all-cause and cardiovascular-related death over the study periods, compared with those who ate the least. They also had lower incidences of colorectal cancer, stroke, coronary heart disease and type 2 diabetes.

What's more, the health benefits rose in line with dietary fibre consumption. That is suggestive of a causal relationship, and a number of randomised controlled trials, the gold standard for medical evidence, show that high-fibre diets lead to lower blood pressure and cholesterol levels. A lack of dietary fibre is estimated to cause more than half a million deaths globally.

When it comes to the gut microbiome's part in this, we know that a community of microorganisms – particularly bacteria – feeds on fibre in the large intestine. Some bacteria can break down the long carbohydrate chains into smaller molecules that they and other microbes can digest. Others take those breakdown products and ferment them, producing short-chain fatty acids such as butyrate. "It's an ecosystem," says Louis.

This benefits us in many ways. "The large intestine prefers butyrate as an energy source over other molecules," says

ALVAREZ/GETTY IMAGES

New studies are showing ever more reasons to eat up your greens

Louis, so the microbes that produce it are indirectly nourishing our gut wall. This may help explain why fibre reduces the risk of colorectal cancer. There are also receptors for short-chain fatty acids in many parts of our bodies, which influence our nervous and immune systems.

But it isn't all about the microbiome. Fibre also leads to us feeling less hungry by stimulating the release of an appetite-reducing hormone called PYY in the small intestine, plus it slows the absorption of glucose into the blood.

With this in mind, how much fibre should you eat, and what kind? The World Health Organization recommends adults get at least 25 grams per day; in the UK, it is 30 g. This is equivalent to the fibre content of 12 to 14 slices of wholewheat bread.

Most of us fall woefully short of this. A 2024 study of more than 2000 adults in Switzerland found that only 13 per cent met the recommended guidelines of 30 g per day, with less fibre consumed by those with the highest intake of ultra-processed food. In the UK, on average people get only 15 g per day, but the situation seems to be worse in the US, where a 2017 study discovered that only around 5 per cent of the population met recommended guidelines. This deficit may be exacerbated by the trend towards low-carb eating, as it is difficult to get sufficient fibre from fruit and vegetables alone.

One way to boost intake is to eat foods that have been supplemented with extracted fibre or synthetic fibre made from ingredients of plant origin. However, unlike for whole foods, "there is no substantiated clinical epidemiological evidence" for health benefits from these forms of fibre, says Mann. "I do not feel that degree of comfort to tell people that they can have extracted or synthetic fibre." The good evidence is for diets where the fibre comes from naturally fibrous foods.

There is also emerging evidence that different kinds of fibre have differing effects. A 2023 review found that insoluble fibre seemed to be more effective than the soluble form at reducing the risk of death from cancer and cardiovascular disease. It also found that fibre from whole grains, cereals and vegetables was associated with lower all-cause mortality, while that from nuts and seeds specifically reduced the risk of death from cardiovascular disease. Similarly, Mann says fibre from legumes seems to have the strongest effect on blood glucose levels, while cereal fibre tends to mostly affect the bowel.

So, as ever with food, variety is good. "Eat lots of plant-based foods, especially vegetables and fruits, wholegrain cereals, pulses – peas and beans – and nuts," says John Mathers at Newcastle University in the UK, "all of which are good sources of dietary fibre." **Michael Marshall**

DO ANTI-INFLAMMATORY DIETS WORK?

It is one of the scourges of life in the modern world: chronic inflammation. This unhelpful response by the body's immune system is linked to accelerated ageing and conditions such as stroke and heart disease.

What if we could dampen it down by consuming certain foods, such as spinach, walnuts and salmon? That is the promise of anti-inflammatory diets, often advocated in vague terms by the media and nutrition industry. That might prompt eye-rolling from the scientifically minded. But recent research reveals that this approach isn't as faddish as it sounds and paints a nuanced picture of the links between food, inflammation and our long-term health.

Inflammation is a crucial part of our response to injury and disease. But when the body continues to deploy it even when there is no trauma, this results in chronic inflammation. Exactly why this occurs is unclear, but genetics, environment and lifestyle play roles. It can be detected by measuring certain chemical markers in the blood, and has been increasingly linked with poor health.

"Chronic inflammation is a driver of many common diseases, including cardiovascular disease, cancer, arthritis and dementia," says John Mathers at Newcastle University in the UK. It has also been implicated in some mental health conditions.

But how much influence can our diet have on this complex process? To find out, we first have to define exactly what an anti-inflammatory diet is. "This is a disputed ›

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area," says Mathers. "There are several competing systems for characterising pro and anti-inflammatory diets."

One of the most widely used metrics is the Dietary Inflammatory Index (DII), first described in 2009. This classifies foods or the nutrients in them, such as carbohydrates and saturated fats, according to their tendency to increase or decrease those chemical markers in blood. Broadly speaking, anti-inflammatory foods feature heavily in the Mediterranean diet – fresh fruit, olive oil, green leafy vegetables, nuts and oily fish – while simple carbohydrates, fried foods, red meat, processed meat and high-fat dairy are pro-inflammatory.

Many of us now eat a diet that triggers inflammation. For instance, a study published in September of more than 34,500 adults in the US found that, overall, 57 per cent had pro-inflammatory diets. Worryingly, this figure was higher for Black people, men, younger adults and people with lower education and income, leading the study's authors to conclude that "socio-economic disparities in health may be partially explained by the inflammatory potential of diet".

But how does this process play out in the body? Here, the picture has become clearer over the past decade. We now know that key players are the microbes in our gut, which can break down constituents of food to produce compounds that either trigger or dampen inflammation. For example, plant fibre feeds certain microbes in the large intestine, enabling them to make short-chain fatty acids, "which have anti-inflammatory effects", says Petra Louis at the University of Aberdeen in the UK (see "What's the real supernutrient we don't get enough of?", page 36). "A fibre-poor diet will be more pro-inflammatory."

A number of clinical trials have convincingly demonstrated that anti-inflammatory diets (by far the best studied being the Mediterranean diet) can reduce markers of inflammation in the blood. A bigger challenge, however, is working out what difference this makes to our long-term health.

The best picture we have of this is from two wide-reaching reviews from 2021, focusing on studies of diets that relied on the DII, ignoring other purported anti-inflammatory versions. One found "convincing" evidence that lower-DII diets cut the chance of having a heart attack, with "highly suggestive" evidence that low-DII diets reduce the risk of certain cancers, notably colorectal, and of all-cause mortality over the study period.

For most health outcomes, however, ranging from breast cancer to depression, there was little or no evidence for benefits.

The second review found "moderate certainty" for low-DII diets reducing cardiovascular disease, colorectal cancer and all-cause mortality.

Another way to investigate the health impacts of anti-inflammatory diets is to think about the effects of foods that shouldn't be in them. Growing evidence suggests, for example, that a diet rich in sugars and fatty acids is associated with a higher risk of developing Alzheimer's. But though inflammation is a risk factor for this condition, it is one of many, including type 2 diabetes. As a result, the diets that seem to offer protection are those already recognised as broadly healthy: low in processed foods, saturated fats, salt and sugars.

"To actually talk about an anti-inflammatory diet, you're really talking about a dietary pattern that is generally healthy," says Jim Mann at Otago University in Dunedin, New Zealand. He says the foods typically included in anti-inflammatory diets would, in any event, be recommended by "any dietitian who's worth their salt". **MM**

> "The shock discovery is that our body's response to food is highly idiosyncratic"

IS PERSONALISED NUTRITION WORTH IT?

Consider two slices of bread, one from an artisanal sourdough boule, the other from a cheap, mass-produced white loaf. Which do you think is healthier? The correct answer is that you don't know until you try. Some people will have an unhealthy reaction to the cheap stuff, with surging blood sugar levels. But others won't, and instead have a sharp rise in blood sugar after the sourdough. Some will surge on both, others barely at all.

The same is true for other foods and other nutrients, especially fats, which can also surge dangerously in the bloodstream after eating. How our metabolisms respond to food is highly idiosyncratic, a shock discovery that is upending decades of nutritional orthodoxy and promising to finally answer that surprisingly knotty question: what should we eat to stay healthy?

Increases in blood glucose and lipids are quite normal after eating, but if they go too high too quickly – called spiking – they can cause trouble. Frequent spikes in glucose and a type of fat called triglyceride are associated with the risk of developing diabetes, obesity and heart disease. For decades, nutrition researchers assumed that all humans responded to a given food in roughly the same way, with uniform increases in blood sugar and fats.

Under that assumption, dietary advice was simple and one-size-fits-all. Reduce consumption of the foods that cause spikes. Unsurprisingly, those were mostly ones high in sugar and fat. Such thinking also underpinned the development of the glycaemic index (GI), an influential measure of how quickly the body converts a foodstuff into glucose, which then enters the bloodstream. High GI foods include baguettes and sugary fruit. For low GI, think wholegrains and leafy vegetables. The higher the GI, the unhealthier the food. Or so the story went.

Over the past few years, nutrition researchers have thoroughly debunked that assumption. Differences in genetics, circadian rhythms and the make-up of our gut microbiomes translate into highly personalised responses to food. As a result,

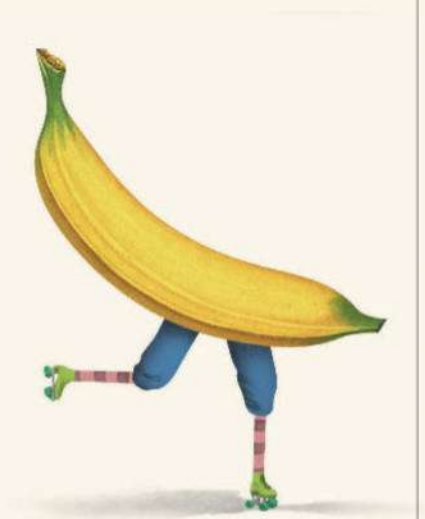
we now know that there is no such thing as a healthy diet that works for everybody.

That doesn't mean there is no such thing as a healthy diet at all, however – it is just that it needs to be individualised. That is the goal of precision nutrition, also known as personalised nutrition.

Research on how to do this has been going on for some time. In 2018, a team led by Tim Spector at King's College London launched the Personalised Responses to Dietary Composition Trial (PREDICT) to measure people's metabolic responses to food, with the ultimate goal of designing individualised healthy diets.

In the first phase, the researchers recruited more than 1000 people, took various biometric measurements including genomes and microbiomes, fed them identical meals and then measured their glucose and fat responses – which turned out to be highly variable. From this, it was possible to roughly predict other individuals' responses to food based on their biometrics alone, which suggested that diets could be personalised without having to actually measure blood glucose and fats.

PREDICT is still ongoing, with around 25,000 subscribers to the Zoe nutrition app now taking part in the latest version. However, the results are in from a smaller, related experiment that gives a flavour of what we might expect. Based on their responses to food, 177 participants were given personalised dietary advice for 18 weeks via the Zoe app, and followed up to see any health impacts. Roughly the same number received generic dietary advice. The participants given personalised advice had lower blood triglyceride levels at the end of the programme and also lost weight and shrank their waist circumference, although there were no differences to other measures including insulin, glucose and cholesterol levels.



MATTHEW ASHMORE/ALAMY

Each of us has a different metabolic response to eating the same bread

"Importantly, we also showed that those who were most adherent to their personalised nutrition programme saw the greatest improvements," says Spector, who is a co-founder of Zoe.

The proof of the pudding will come from larger trials like PREDICT. The US National Institutes of Health also has a major research effort on precision nutrition with a goal to "fundamentally transform nutrition science". Last year, it started recruiting 10,000 people to take part in an experiment on individualised responses to food. There are no results as yet.

Still, even if they are positive, cooking up this research into widespread dietary advice will be a tall order. "The costs of translating these data for public health improvement are prohibitive and not practical at this time," says Regan Bailey at Texas A&M University. Likewise, a 2023 report from the UK's Food Standards Agency concluded that the benefits of personalised nutrition "seem somewhat marginal when compared to what is already understood about a healthy diet". **GL**

ARE FERMENTED FOODS ALL THEY ARE CRACKED UP TO BE?

Humans have been fermenting food and drink for at least 13,000 years – and touting the health benefits for nearly as long. But despite our long history with them, we are only beginning to determine whether these foods are actually beneficial for our health.

Unlike our ancestors, however, we now know how fermentation works: microbes such as certain yeasts and bacteria break down sugars in grains, fruit, vegetables and dairy products in a way that prevents them from spoiling and produces unique flavours. But what does this mean for our health?

Numerous studies have linked fermented foods – particularly dairy versions – to a reduced risk of heart disease, type 2 diabetes and obesity. For instance, a 2023 study involving more than 46,000 adults living in the US found that eating fermented foods was associated with lower blood pressure, body mass index and waist circumference.

But much of the research lumps all kinds of fermented foods together, and given the health halo around these products, we know that people who consume them probably tend to look after their health in other ways too. Both of these factors make it difficult to determine what is actually providing any observed benefits.

That said, the case is strongest for yogurt. Many large studies have linked its consumption to improvements in immunity, bone density and longevity and to a reduced risk of cardiovascular disease and high blood pressure. Yet determining cause and effect from these observational studies is tricky and some of the benefits may have nothing to do with fermentation. For example, yogurt is high in calcium, a nutrient helpful for stronger bones. ›

However, earlier this year, the US Food and Drug Administration announced that consuming at least three servings of yogurt per week may lower the risk of type 2 diabetes. This was based on multiple studies, including one that involved more than 192,000 adults living in the US. It found that increasing yogurt consumption by more than half a serving per day was associated with an 11 per cent lower risk of developing type 2 diabetes over a four-year period.

Links between type 2 diabetes and unfermented dairy products are less robust, suggesting that these benefits are to do with the microbes found in yogurt, says Simin Meydani at Tufts University in Massachusetts. We know that bacteria used to ferment yogurt release compounds called bioactive peptides that are otherwise locked up in milk proteins and are believed to help lower blood pressure and regulate immune responses.

Live bacteria in yogurt can also affect the make-up of the gut microbiome, which plays a crucial role in regulating immune responses and metabolism. "The idea is that by providing bacteria through yogurt and introducing them into the gut, we are increasing the [amount of] beneficial bacteria," says Meydani.

> "People who consume fermented foods tend to look after their health in other ways too"

How other fermented foods might provide health benefits is less clear, says Isabelle Savary-Auzeloux at the French National Institute for Agriculture, Food and Environment. We know, for instance, that dietary fibre feeds gut microbes and helps them flourish (see "What's the real supernutrient we don't get enough of?", page 36). Fermented and raw vegetables contain similar amounts of fibre, so it may be that, not the fermentation, that makes a difference.

To find out, Justin Sonnenburg at Stanford University in California and his colleagues put 36 adults on a diet rich in either plant-based fibre or fermented foods such as yogurt, kombucha, sauerkraut and kimchi. On average, those in the first group ate 45 grams of fibre per day without increasing their intake of fermented produce. Meanwhile, participants in the fermented food group ate an average of six servings of such fare daily without increasing their fibre intake.

After 10 weeks, those on the high-fibre diet saw no significant changes in the diversity of gut microbes or in blood levels of inflammatory markers, which can be used to track immune response, including chronic inflammation associated with conditions like heart disease, type 2 diabetes and cancer.

In people on the fermented food diet, however, researchers did see an increase in gut microbiome diversity. This was most strongly associated with consuming two things in particular: yogurt and vegetable brine, the liquid that fermented vegetables such as kimchi soak in. Compared with the start of the study, participants eating fermented foods also had lower levels of inflammatory markers. It appears fibre alone isn't responsible for the benefits.

What's more, researchers thought they would see the bacteria in fermented foods take up residence in participants' guts. Few did. Instead, their presence seemed to somehow carve out a niche for new or previously undetected bacterial strains to flourish.

All of this suggests that fermented foods, especially yogurt, may give our health a boost. But it is still far from conclusive, says Meydani. More controlled trials are needed, as is a more detailed understanding of specific bacterial strains. "Depending on the type of bacteria, you could have different health benefits," she says.

If you do decide to eat more fermented foods, Savary-Auzeloux recommends finding a trusted source and cautions against the do-it-yourself route. Inexpert at-home fermentation can foster harmful pathogens like *Escherichia coli* or *Salmonella*, potentially leaving you with a nasty case of food poisoning instead of a happy gut microbiome.

Grace Wade ▮

GA_NA/ALAMY

Studying the health impact of fermented foods is complicated

Total immersion

An extraordinary experiment aims to combine virtual reality and psychedelic drugs to unpick how our brains separate fantasy from reality, finds **Ruby Deevoy**

PETER REYNOLDS

IN CERTAIN circles, the potent psychedelic N,N-dimethyltryptamine (DMT) is known as the "spirit molecule" for its peculiar ability to transport people into other worlds. Those who take it commonly experience vibrant colours, abstract geometric patterns – and even meet elves and aliens – all in a way that feels completely real.

That might all sound about as far from the realm of empirical science as you can get – but not for neuroscientist Zeus Tipado. In his lab in Maastricht, the Netherlands, he is planning an outlandish experiment in which he will monitor the brains of people dosed with DMT while they wear a virtual reality headset. The hope is that by observing what happens when we slip into another form of reality, we can fathom how our minds construct the one we experience in everyday life. "Our brain is easily deceived as to what reality is," says Tipado.

Already, he has found tantalising hints of a new brain network that he thinks might underlie the feeling we have of being immersed in a world – be that real life, VR or a drug-induced trip. He hopes to identify and perhaps even learn to control this hypothetical "immersion circuit". If he can, it might enable us to dial up or down how believable an experience is, create more effective therapies for mental ill-health and produce more visceral training worlds for surgeons or firefighters. It would also, of course, be a huge breakthrough in neuroscience.

We don't fully understand how our minds create the seamless experience of the world around us. But one leading idea is that the brain is a kind of "prediction machine" that actively constructs reality by contrasting personal expectations, based on past events, with direct data from our senses.

When there is a difference between internal predictions and our senses, we are left with a "prediction error", which the body tries to minimise by gradually updating our internal model of ourselves and the world as new sense data comes in. "Everything we experience is a kind of pragmatic construct," says cognitive philosopher Andy Clark at the University of Sussex in the UK. "All of our predictions are geared towards smoothly guiding actions, because it's only actions that will keep us alive."

This predictive model of ourselves is built in a hierarchy of layers. The so-called higher levels contain abstract ideas such as who we are and what reality is, whereas the lower levels are concerned with more concrete things like colour and shape. There is a two-way flow of information, with predictions cascading down from these higher levels in a series of feedback loops, while sense data from our eyes, ears, nose and skin rises up from the lower levels.

Psychedelics are widely thought to exert some of their strongest effects at higher levels of predictive processing, says Clark. For example, activity in the brain's default mode network – which is broadly thought to help ›

us assess past events, plan for the future and construct our sense of self-awareness and ego – is dampened by many psychedelics. Recent research by Christopher Timmerman at Imperial College London found that DMT specifically has this effect on the default mode network while also increasing connectivity between different brain regions and collapsing the organisation of the brain's hierarchies.

"Whenever you take psychedelics, the location of this information gets mixed up," says Tipado. Simple, low-level concepts like colours and shapes are processed in higher levels of the visual cortex. Meanwhile, complex concepts, like the details of faces, are processed in lower-level regions of the visual cortex. "It's like putting a PlayStation 5 disc in a PlayStation 2. It's not compatible," he says. "That's why we have visual experiences that are very counterintuitive."

This disruption makes some sense within an overarching model of how psychedelics act on the mind – called relaxed beliefs under psychedelics (REBUS). Computational neuroscientist Karl Friston at University College London and Robin Carhart-Harris at the University of California San Francisco, who came up with the model, suggest that psychedelics specifically relax the grip of our high-level expectations of what reality should be like. Reducing top-down control in this way then frees up the flow of bottom-up sensory information so that it exerts more influence.

"Psychedelics suddenly give access to an almost raw feed of our visual world"

All of which could help explain the therapeutic effects of psychedelics, which are combined with talking therapy in promising treatments for depression, PTSD and addiction. According to REBUS, relaxing high-level beliefs allows us to reframe the unremitting thought patterns and behaviours that occur in mental health conditions like these.

By building on predictive processing models like this, Tipado aims to figure out what happens when we become so immersed in our perceptions of alternate realities that we accept them as physically real. He agrees that the relaxation of high-level beliefs can dramatically alter our experience of reality, but argues that the influential and causal role played by lower levels in the hierarchy has been overlooked. Leor Roseman at the University of Exeter, UK, has thought about these processes independently and is broadly on the same page. "There's not just processes from the top down or bottom up," he says. "There's an interplay. It's more dialogical."

Tipado's research considers how this dialogue plays out in the brain's visual system. "Out of all the perceptual domains, the single thing that is a global experience in psychedelic trips is an intense visual experience," he says. A 2018 study by Roseman and Carhart-Harris found that positive therapeutic outcomes in psychedelic-assisted therapy correlate to some extent with the reported strength of this visual modification, among other things.

This has taken Tipado on an unexpected detour into the realm of ocular science and the intricate way that the eye connects to the visual cortex. "We're trying to draw attention to the bottom-up processing of the eye," he says, and how it alters our subjective experience of immersion – broadly defined as the perception of being physically present in a non-physical world.

In particular, he is focusing on the role played by amacrine cells in the retina, which are thought to act as inhibitory filters for the visual data we receive from the outside world. In 2015, Satoshi Watanabe and his collaborators at Osaka University in Japan genetically modified mice so they were born without such cells.. They found these "filterless" mice performed better at tests involving identifying the edges and outlines of objects in darkness. "If you don't have amacrine cells, then you can detect significantly lower-contrast objects," says Tipado. However, there are many different types of amacrine cells, and the precise filtering mechanisms are unknown.

Behind closed eyes

Tipado also suspects that amacrine cells are the key to understanding the immersive visuals experienced in psychedelic trips. In a paper published in April, he pointed to the similarity between the behaviour of mice

MERIDITH KOHUT/NEW YORK TIMES/REDUX/EYEVINE

Virtual reality could be used during psychedelic-assisted therapy

bred to lack these cells and the common psychedelic phenomenon of "closed-eye visuals", whereby incredibly vivid colours, shapes and even entire worlds are perceived behind shut eyelids. Amacrine cells also contain a lot of 5HT2a receptors, which are the same type activated by psychedelics like DMT and psilocybin. The alteration of amacrine cells by psychedelics through their 5HT2a receptors may enhance the amount of visual sensitivity in darkness, including behind closed eyelids, leading to these unusual visual experiences. "We're suddenly given access to an almost raw feed of our visual world," says Tipado.

He suggests that these cells might even be the gateway to the wholesale disruption and alteration of the brain's predictive processing hierarchies, which underpin all immersive visual perceptions – psychedelic or otherwise. "The possibility that a trip might be initially triggered because amacrine cells aren't inhibiting visual information could open up a whole new realm of understanding," he says. Roseman agrees that amacrine cells play a role in visual psychedelic experiences but adds that he "wouldn't go as far as saying they are the source of visions".

To test these ideas, next year Tipado plans to observe how the visual cortex is activated during an immersive VR experience before, during and after a DMT trip. He has designed the experiment to try to modulate amacrine cell activity. Rather than mind-blowing visuals melting into each other, the VR world is sparse: a 360-degree surrounding of *Eigengrau* – German for intrinsic grey – which replicates the darkness you see when you close your eyes. This low-quality, low-contrast visual information increases the likelihood that the brain makes a prediction error, says Tipado. "It's like when you're in a dark room, you might mistake a coatrack for a person."

"Is immersion an actual network of brain areas that can be dialled up and dialled down?"

By combining DMT with VR, he hopes to draw people into a series of immersive realities that they believe are real to greater or lesser degrees. "We can really play around with this sort of state of visual ambiguity," he says. A functional near-infrared spectroscopy headset, which assesses brain activity by shining light through the skull and observing how much is absorbed by brain tissue, will then be used to search for possible hallmarks of immersion in the visual cortex. "We're investigating the areas of the brain responsible for immersion," he says.

Tipado says his unpublished pilot studies suggest that there is overlap in activity in the visual cortex in people experiencing either immersive VR or DMT realities. These common signals could hint at a new brain network specifically related to immersion. "We're assuming that this could represent some sort of circuit of brain connectivity," he says. "Is immersion an actual network of brain areas, just like how the default mode network is a network of brain areas that can be dialled up and dialled down?" he asks.

However, it is fair to say there is still no published evidence to back up Tipado's claims of an overarching immersion network. And Marco Aqil, a neuroscientist at the Spinoza Centre for Neuroimaging in the Netherlands, suggests that the underlying architecture of VR immersion may differ from psychedelic immersion.

Still, Tipado is upbeat. "Figuring out if the brain constructs reality in the same way regardless of it being actual reality, virtual reality or a pharmacological reality induced by psychedelics, could help us comprehend augmented reality as a whole," he says. "And potentially how our minds construct day-to-day reality, too."

From an entertainment perspective, this could enable gaming worlds that are fundamentally more believable. "That's a low-hanging fruit," says Tipado. It could also lead to more effective virtual offices or training programmes for pilots or doctors, for example.

Then there is psychedelic-assisted therapy, during which people are often given blindfolds to reduce their visual stimulation. Some other approaches go even further, attempting to remove the subjective experiences of psychedelics altogether. However, Roseman points out that "a lot of the emotional insights of the spiritual experience have a visual or imaginary quality". Tipado agrees that more attention should be paid to the importance of vision in these therapies and he hopes to use immersive VR to precisely guide the experience. "The future needs to be a little bit weirder," he says. ▮

Ruby Deevoy is a psychedelics and cannabis journalist based in the UK

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The science of exercise

Working it out

What is the most efficient way to exercise? The answer is complicated – and depends on the person, finds **Grace Wade**

Grace Wade is a health reporter for *New Scientist* based in the US

WHEN I first started my fitness journey, I wanted to maximise my workout. If I was going to be sore and sweaty, I figured I might as well make the most of it.

Building fitness requires pushing your body to do more activity than it is used to. A good barometer for how hard you are exerting yourself during exercise is therefore the number of calories you burn. So, what exercise uses the most calories? It depends.

Research has consistently shown that aerobic exercises such as running, swimming or cycling burn more calories per minute than resistance training. For instance, vigorously swimming burns an average of 13.3 calories per minute for someone weighing 80 kilograms. The same person would expend roughly 4 calories a minute when doing moderate weight training.

Some studies show you can burn even more calories with high-intensity interval training (HIIT). These workouts involve performing cardiovascular and resistance exercises at near-maximum effort in repeated bursts of up to a minute with short breaks in between. A 2015 study involving nine active men found that, on average, a HIIT workout with a hydraulic resistance machine burned 12.6 calories per minute. Lifting weights and running on a treadmill used about 8.8 and 9.5 calories per minute, respectively.

The key to burning the most calories is using as many muscles as possible at the highest intensity possible. This is why jumping rope or skipping is such a great exercise. Doing so at a fast pace can burn around 15.9 calories per minute, or 478 calories in half an hour, for someone weighing 80 kg.

AZMANL/GETTY IMAGES

The issue is that not many people can jump rope at that intensity for a full 30 minutes. It is therefore crucial to account for duration when determining which exercise burns the most calories.

Let's say someone weighing 80 kg vigorously jumps rope for an impressive 10 minutes straight. They would burn about 159 calories. Compare that with a 35-minute walk at a brisk pace, which is not only more feasible but also expends roughly 176 calories. Opting for a less intense workout may actually end up burning more calories than choosing a more strenuous one if you are able to exercise for longer.

Another factor to consider is frequency. Swimming is a great exercise for burning calories, but not many people can access a pool every day. If someone who is 80 kg was able to vigorously swim for a half hour twice a week, they would expend 798 calories per week. If they walked briskly for 30 minutes daily, they would burn 1057 calories a week.

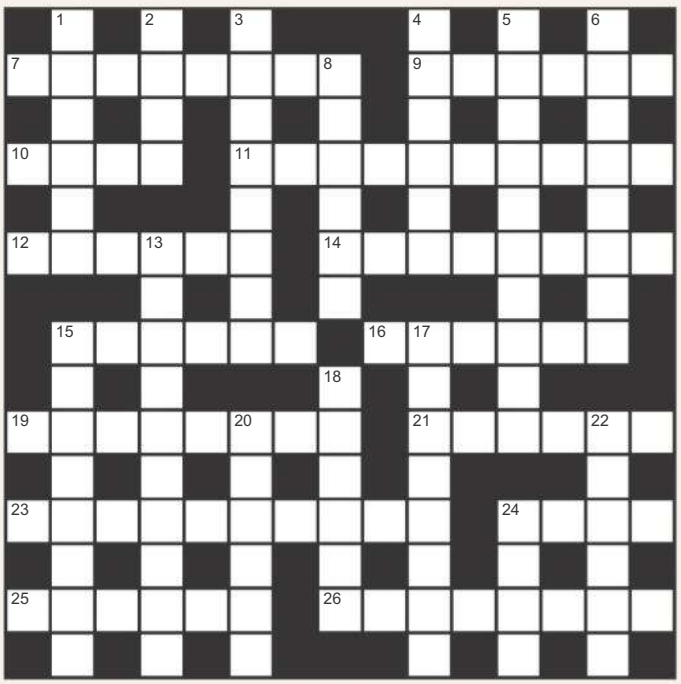
Ultimately, the exercise that burns the most calories is the one you can do consistently. For me, that means finding workouts I enjoy rather than dread, such as dance classes or yoga. ▮

The science of exercise appears monthly

Next week
Dear David

These articles are posted each week at newscientist.com/maker

Quick crossword #170 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

7 Deflect, at speed (8)
9 × 50% (2,4)
10 NaCl, for one (4)
11 2011 sci-fi film directed by Duncan Jones (6,4)
12 6th planet from the sun (6)
14 Henry ___, inventor of a steel manufacturing process (8)
15 Spin, turn (6)
16 Viral infection (6)
19 U-shaped curve (8)
21 T.H. ___, "Darwin's bulldog" (6)
23 Remained stationary (5,5)
24 Profound; not shallow (4)
25 Deflect (6)
26 Transit system, usually elevated (8)

DOWN

1 Insect that may be periodical (6)
2 Jan ___, Dutch astronomer (4)
3 Tree that may be horse or sweet (8)
4 Calculation aid (6)
5 Varicella (10)
6 Anatomical balloons (8)
8 Digits that may be opposable (6)
13 Noise at a frequency >20 kHz (10)
15 Response (8)
17 C_2H_4 (8)
18 Ba (6)
20 Bivalve mollusc (6)
22 Vomit-inducing (6)
24 Diesel oil (4)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #276
set by Bethan Ackerley

1 What material did IBM researchers Georg Bednorz and K. Alex Müller discover in 1986?

2 Insects of the order *Ephemeroptera* are more commonly known by what name?

3 In what year was the first expedition to successfully traverse the Northwest Passage by boat completed?

4 What name is given to the outer, visible part of the human ear?

5 The Almagest is an astronomical manual written by which ancient Greek thinker?

Answers on page 47

BrainTwister
set by Christopher Dearlove
#44 Dice and cards

On each turn of a game, we roll three standard dice with faces numbered 1 to 6 and add up the numbers shown. What is the average (mean) value of that total over a long game?

Now suppose instead of rolling dice, we draw three cards from a six-card deck where the cards are numbered 1 to 6. If we put each card back after drawing it and shuffle before drawing another card, does this change the expected value?

If we instead draw three cards without replacement (so the probabilities are no longer independent), what is the average value of the sum?

Solution next week

Rogue agent

If an Earth-sized rogue planet passed through our solar system, missing the planets, how much disruption would it cause?

Alex McDowell
London, UK
It depends on how close it came to any planets. Venus, which is roughly Earth-sized, sometimes gets to within 0.3 astronomical units (45,000,000 km) of Mercury and causes tiny but measurable perturbations in its orbit.

If it misses planets, it might hit their satellites, causing a lot of debris to be thrown off, which could end up raining down on planets. If it came close enough to any body in the solar system, it would significantly perturb its orbit; this may lead to planets colliding or heading into the sun! It might even "steal" moons.

It would also exert tidal forces on planets – perhaps strong enough to deform rocky planets' crusts, leading to quakes and volcanic eruptions. If it came close enough to Earth, such eruptions could lead to mass extinctions.

Planets' axes could also be tilted – if this happened to Earth, it would affect our weather.

"If a rogue planet disturbed the asteroid belt, large rocks could end up hitting the planets in the solar system"

An Earth-sized object would exert the same strength of gravity on Earth's surface as the moon does by the time it was within a distance of eight times the radius of the moon's orbit.

If it disturbed the asteroid belt, large rocks or minor planetoids could end up hitting planets.

Sam Edge
Ringwood, Hampshire, UK
The answer depends entirely upon its trajectory.

Depictions of the solar system in textbooks or online fail to show how colossally large it is, especially compared with the bodies in it, even the sun and the gas giants Jupiter and Saturn.

The result is that the solar system as defined, say, by the aphelion of Neptune (its furthest point from the sun) is essentially empty space. The episode of the UK prison sitcom *Porridge* where they explored this comes to mind – well worth watching.

So for almost all trajectories, the answer would be "very little".

If it came in perpendicular to the orbital plane defining Earth's path around the sun, say half way between the orbits of Mars and Jupiter when they are on the other side of the sun, then it wouldn't cause much of a ripple, especially if it were moving very fast.

However, if it came in on a curved orbit on Earth's orbital plane, it would have a much greater chance of interacting gravitationally with a planet.

Depending on how close and how similar its mass to the encountered planet, that could cause severe shifts in the orbit of the planet and disruption of any moons it has. But again, because of how large the solar system really is, the chances of such a close encounter would still be very slim.

Eric Kvaalen
Les Essarts le Roi, France
If it came near one of our planets, then it would significantly change its orbit, and that could have severe consequences later.

Last year, *New Scientist* published an article about what would happen if a star passed through the solar system. An Earth-sized planet would have a lesser effect, but that study may still give some indication.

The effect depended of course on how deep into the solar system the star came. In some cases the orbits were only slightly altered, but if the star came near the orbit of Earth, it could throw all of the planets out of the solar system completely and immediately.

Another interesting outcome was that initially the perturbation seemed small, but after a million years, Mercury's orbit became quite eccentric and after 10 million years it fell into the sun.

In some cases, Earth's moon is perturbed by a close approach of one of our solar system's planets (such as Venus) and ends up hitting Earth.

Atlant Schmidt
Nashua, New Hampshire, US
That would depend a lot on the intentions of any occupants of that planet.

More seriously, if it became obvious that there was a civilisation on that planet, it would cause massive disruption to our civilisation here on Earth.

EVGENII PUZANOV/ALAMY

Are people really able to pick up the scent of charred sausages in outer space?

This week's new questions

Smell of space **Does space really smell like an overdone barbecue, as astronaut Tim Peake has said? And can the molecules carrying the smell exist in sufficient quantities in a near vacuum?** ***Anne Downer****, Bristol, UK*

End of an era **When I die, what happens to my microbiome?** ***Bill Smith****, Doylestown, Pennsylvania, US*

Cosy spot

Why do cats like to sit on newspapers and magazines?

Caroline Peters
Wokingham, Berkshire, UK
Cats love things that are square or rectangular. Not only do newspapers and magazines fulfil this requirement, but a pile of papers also acts as insulation between the cat and the surface on which the newspaper is laid, so it feels warm.

Of course, if you are trying to read the paper, then the reason is that your cat just wants your attention. They will also sit on any work papers and computer

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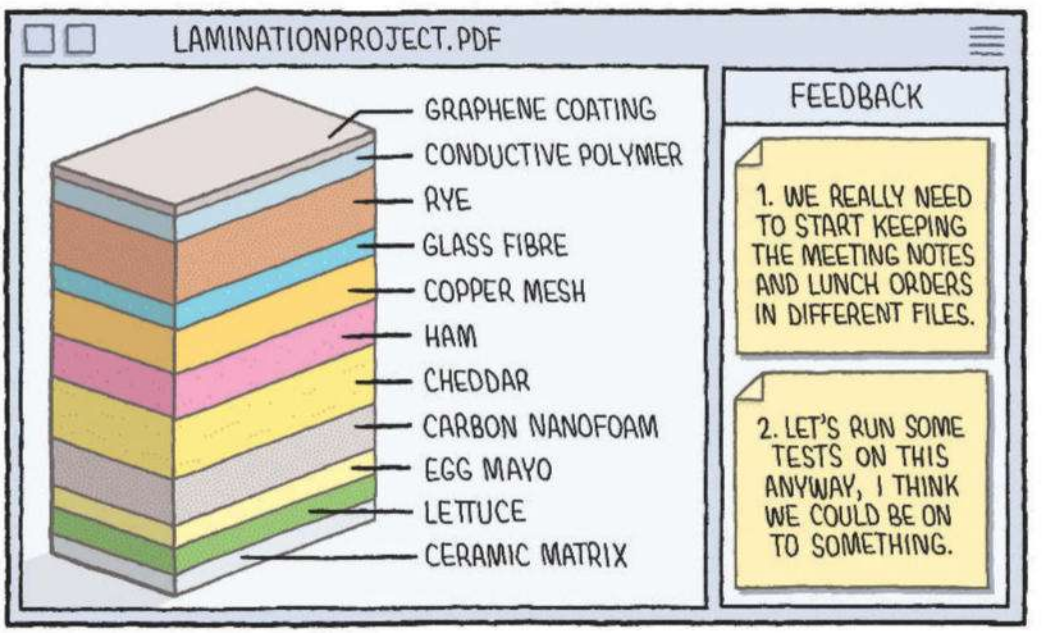
Full terms and conditions at newscientist.com/lw-terms

Tom Gauld
for New Scientist



keyboards for the same reason.

Lastly, if the cat is sitting on a copy of *New Scientist*, then it is looking to see whether its paper on gravity experiments ("Investigation of the effect of feline paw trajectory on pen propulsion") has been published!

David Muir
Edinburgh, UK
Cats are innately expert at appreciating the heat insulating properties of materials. They seek out the places that help them to retain body heat. This may be an evolutionary adaptation to allow them to do less hunting, which is energetically expensive.

On the other anthropomorphic hand, cats may simply like luxuriating in warmth and comfort, just like us. Try lying naked on sheet metal, bathroom tiles or concrete (preferably while in a private place) – it isn't conducive to contentment.

Generally, cats' choice of newspaper seems an excellent balance of good insulation with no jaggy or tickly bits.

"Try lying naked on sheet metal, bathroom tiles or concrete, preferably in a private place – not conducive to contentment"

H. A. White, Jr
St Paul, Minnesota, US
Long ago, I hosted a cat prone to giving loud, lengthy warnings of an imminent upchuck. One evening, so warned, I placed him on a newspaper, holding and comforting him while he conveyed his rejects to the paper, a veritable letter to the editor. From then until his demise, years later, several times a week I would discover a newspaper covered in cat opinion. And that's why cats like to sit on newspapers.

Ametrine Lavender
Hebden Bridge, West Yorkshire, UK
The book *How it Works: The cat* (Ladybirds for Grown-Ups) tells us that once the owner has indicated which book or magazine is interesting, by leaving it open, the cat sits on it and "reads through its bottom". I think this goes a long way to solving that mystery, and I highly recommend this delightful little book to all who observe cats.

John Homes
Via email
Because people will persist in paying attention to the newspapers and magazines, when they should (at least in the cat's opinion) be paying attention to the cat.

Dan Conine
Via email
Why do cats what? ▮

DAN CONINE

Answers

Quick quiz #276 *Answers*

1 The first high-temperature superconductor
2 Mayflies
3 1906
4 The auricle
5 Ptolemy

Cryptic crossword #147 *Answers*

ACROSS 7 Midair, **8** Orb web, **9** Yeti, **10** Nanotech, **11** Katydid, **13** Addle, **15** Sinus, **17** Key West, **20** Water ski, **21** X-ing, **23** Annexe, **24** Hungry

DOWN 1 Tine, **2** Parity, **3** Transit, **4** Wound, **5** Abated, **6** Hercules, **12** Avifauna, **14** Relight, **16** Ureter, **18** Waxing, **19** Ashes, **22** Norm

#43 Consecutive sums *Solution*

We can write 14 = 2 + 3 + 4 + 5.

Any odd number can be written as the sum of two consecutive numbers: $2n + 1 = n + (n + 1)$.

Even numbers that have an odd factor like 3, 5, 7 etc, can be written as a sum of that many terms: e.g. 12, which is 4 × 3, can be written as three numbers centred on 4: 3 + 4 + 5. In the case of 14, we use seven numbers centred on 2, but since the first three of these are -1, 0 and 1, they cancel out, leaving us with the sum above.

The only numbers that can't be expressed this way are those without an odd factor (other than 1) – exactly the powers of 2: 1, 2, 4, 8, 16 and so on.

AdVerts FRom HeLl

Feedback is often both baffled and intrigued by the tricks advertisers will pull to try to sell things, but the latest gambit seems designed to wrong-foot: deliberately odd capitalisation and bad grammar.

During our time spent mucking around on our smartphone, Feedback has repeatedly seen ads for a mobile game that promises the "Hardest LEvel in the HisTory". We have SPent days tRYing to Work out wHy it looks like thaT.

The game in question is called *Go Climb*! It is a puzzle game in which a group of mountaineers ascending a peak have got their safety lines tangled and the player must untangle them. So it is, essentially, the back of Feedback's TV, except it has been gamified and is also at least somewhat possible to solve.

Feedback initially wondered if this was a case of non-English-speaking developers skimping on translation costs. There is precedent for this: back in 1991, the Japanese space shooter *Zero Wing* was released in Europe with a notoriously shonky translation. As a result, in the introductory cutscene, an alien invader announced: "All your base are belong to us." After this was rediscovered in the late 1990s, it became one of the most widely shared internet memes of the time.

However, a closer look at *Go Climb!* suggests something else is going on. It is made by a company called FOMO Games. The firm is based in Turkey, but its staff clearly have an excellent command of English, as evidenced by the information provided about all its other games, not to mention the gloriously corporate text on its website explaining that "FOMO stands for Fear Of Missing Out, which defines our product vision and culture."

Instead, Feedback suspects the bad English is intentionally designed to get our attention. In line with this, the advert has other odd features that add to the off-kilter feeling. Notably, in it, the mountaineers from the game are replaced with astronauts in spacesuits drifting around against a starry backdrop, so the game's title makes absolutely no sense. It was only when we looked at the game in an app store that the mountaineering theme was revealed and things became clear.

This seems to be a new and devilish way to advertise a product online: purposely make a complete hash of your ad and hope this intrigues people enough to get them to click through.

And on some level it worked, because here we are. But Feedback hasn't downloaded the game. On principle, we don't believe in rewarding deliberately bad spelling.

Twisteddoodles *for New Scientist*

I KNOW THE EXPERIMENT DIDN'T WORK OUT, BUT ANY RESULT IS STILL A RESULT.
WHERE AM I MEANT TO PUBLISH IT? "THE JOURNAL OF MISTAKES"?
@twisteddoodles
THE JOURNAL OF MISTAKES
HOW NOT TO DO THIS EXPERIMENT IF YOU WANT IT TO WORK
GAMMA RAYS LEADING TO SUPERPOWERS

Got a story for Feedback?
Send it to feedback@newscientist.com
or New Scientist, 9 Derry Street, London, W8 5HY
Consideration of items sent in the post will be delayed

Monkeys in politics

At the time of writing, the US presidential election is imminent and Feedback is trapped in an endless cycle of news stories reporting polls, pundits endlessly reinterpreting said polls, and then more polls. It is a terribly long-winded way of saying "we don't know what's going to happen".

Now, our colleague Alexandra Thompson has highlighted an important new contribution to the field of psephological forecasting: a paper titled "Monkeys predict US elections".

Sadly, this doesn't involve placing an infinite number of monkeys into voting booths. Instead, researchers showed monkeys pairs of photos of candidates from senatorial and gubernatorial elections.

The monkeys spent more time looking at the losers than at the winners. This seems like a peculiar form of torture for politicians: not only did you lose, it says, but monkeys stared at you judgmentally.

The study extended previous work showing that children can identify the winners and losers in elections based purely on photos of the candidates. Both the children and the monkeys were picking based on face shape, with square jawlines being the key sign of an improved chance of victory.

Who would do such a study? Three of the researchers are at the University of Pennsylvania, but the fourth is based at a Portuguese institution called the Champalimaud Center for the Unknown. Feedback isn't quite sure what to make of that.

It does seem that unconscious factors play into our voting decisions. It is often claimed that taller candidates tend to win US elections, and there appears to be some truth to this.

A 2013 study pulled data on all US presidential elections to date and found that taller candidates won more of the popular vote – although this didn't translate to them being more likely to actually be elected. In what can only be described as double nominative determinism, one of the authors is a social psychologist called Abraham Buunk.

Readers who are invested in the outcome of the US election are hereby advised: whatever you do, don't look up Donald Trump's and Kamala Harris's respective heights.

One more for the road

In such stressful times, like many people, Feedback has turned to the soothing alternative reality of *The Great British Bake Off* (*The Great British Baking Show*, if you are in North America).

There are all sorts of fascinating and delicious things to learn about the materials science of breads, cakes and biscuits, but we just want to point out that the show's home economist, who produces all the sample biscuits, tarts and desserts for the technical challenges, is called Hattie Baker.

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Share price total return (£)	11%	16%	16%	48%	268%
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1 Over the ten years to 31 July 2024, the US dollar NAV per share compound annual growth rate ("CAGR") was 13% and the public market comparator (the FTSE All-World Total Return Index) CAGR was 9%.

2 Please also note the "NAV per share" percentages in the table above reflect the US dollar monthly estimated NAV per share.

3 HVPE introduced an additional US dollar share price on 10 December 2018; from this date onwards, the actual US dollar share price, as reported by the London Stock Exhange, has been used. Prior to this date, the US dollar share price had been converted from the sterling share price at the prevailing exchange rate. The share price total return figures have been adjusted for the redemptions which occurred in October 2013 and October 2014.